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The meaning of science

The century in which we live has witnessed an advance in man's command of the material universe unexampled in the previous history of the world. Indeed, it has been asserted by an eminent sociologist that the progress of the last forty years equals, and perhaps surpasses, that of the whole period of human history from the dawn of civilization up to the year 1900. The nations of the world now have at their disposal unparalleled power over natural substances and forces—a power which has been placed in their hands by the expansion of scientific knowledge, and which may be used for good or for evil purposes. Whether man has reached a stage in his moral evolution at which he can be trusted to turn these gifts to predominantly beneficial ends is a matter with which we are not for the moment concerned.

Concurrently with these advances in applied science has come a reformulation of fundamental theories. This has altered our concepts of that world-model which is sometimes naïvely taken to express the ultimate reality of things, and altered them in a manner that can only be described as revolutionary. It has also fostered a tendency to ask the questions 'What is meant by the term science?' and 'What are the objects and scope of a scientific theory?'.

Our nineteenth-century forbears had a simple answer to the first of these queries. Science to them was just 'organized common sense,' and inasmuch as their very successful physical theories were an extrapolation of large-scale mechanical notions to cover atomic phenomena the answer may be deemed to have been adequate at that time. But in these days of quantum mechanics and probability-smears the answer to the same question is not expressible with similar simplicity. What, then, are the aims and objects of the man of science in his quest for truth—or what he regards as truth? The reply to this second query may be found to include that to the first.

We have our being in a jungle of sense-impressions. The stars wheel in majestic circles around the pole; the planets move with apparent irregularity amid the so-called fixed stars; the tides ebb and flow; the barometer rises and falls; April showers pierce to the root of the drought of March; figs do not grow on thistles; a respectable law-abiding citizen suffers a brain injury and becomes an irresponsible criminal: these are but a scattered few from thousands of facts which meet us on our journey through life, and which, our minds being what they are, demand a coherent explanation. It is the object of science to give that explanation; though whereas our ancestors were wont to attempt to answer the question 'Why?' the man of science is today content if he can describe the 'How?' of the particular phenomenon in which his interest lies.

Newton, indeed, has the root of this matter in him. His famous *Hypotheses non fingo* must be read in its context if we would grasp its true significance: 'But hitherto I have not been able to discover the cause of those properties of gravity from phaenomena, and I frame no hypotheses; for whatever is not deduced from the phaenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phaenomena, and afterwards rendered general by induction.'

Restricting ourselves to the consideration of the physical sciences, let us for a moment review the implications of a scientific theory. The great structure of nineteenth-century physics was based on Newtonian mechanics, which gave clear and precise definitions of such concepts as mass, force, momentum, energy, and the like. The laws of

dynamics based on these concepts sufficed to describe with almost incredible accuracy an extraordinarily wide range of phenomena, from the motions of the planets down to the behaviour of the balls on a billiards table.

The scheme was extended into a conceptual submicroscopic world of atoms, and served to describe certain large-scale phenomena and to predict others, again with an accuracy that may be restrainedly designated as marvellous. The pressure of a gas, for example, was interpreted and calculated in terms of the movements of its molecular constituents; and whereas common observation shows that the viscosity of a liquid decreases rapidly with rise of temperature, the kinetic theory of the billiards ball atom predicted an increase of viscosity in a gas as the temperature rises—a prediction that was later confirmed by experiment. Such instances might be multiplied almost indefinitely, and it is small wonder that the rank and file of nineteenth-century scientists—and indeed some of the leaders—were convinced that their atoms were as real as the benches and Bunsen burners in the laboratories.

So with the ether of space. Lord Kelvin said with characteristic vigour: 'This thing we call the luminiferous ether . . . is the only substance we are confident of in dynamics. One thing we are sure of, and that is the reality and substantiality of the luminiferous ether.' But alas! for such optimism. We are not so convinced today of the reality and substantiality of a luminiferous ether as was Kelvin. Even our concept of the atom has become complicated almost out of recognition and bears no resemblance to the perfectly elastic, spherical atom of the Newtonian epoch.

In truth, a scientific theory is concerned with phenomena rather than with any 'reality' that may be supposed to lie behind them; its object, as Kirchhoff put it, is to describe, in the simplest possible fashion, the happenings in the physical world around us. If we can by means of a scientific theory correlate known facts and predict new ones the theory will have done for us all that a theory can do or is expected to do. Scientific theories have no permanence. They change with each generation and with a wider knowledge of perceptual facts; but—and it is a 'but' that the lay mind too frequently fails to appreciate—each new theory subsumes the one it displaces, in the sense that it is merely a closer description of the same phenomena or a wider generalization embracing a greater number of phenomena.

It cannot be denied that, in the middle years of the nineteenth century, there was a phase of scientific materialism which for some time had a considerable vogue. England and Germany were the countries most affected; but even they were not entirely swept by the movement, and wiser judgments were soon uttered by leading scientists. The privates in the scientific army may have been given an ingenuous realism, but the staff in general held clearer views concerning the limitations of a scientific theory.

Science, then, is concerned with phenomena, that is, with appearances. Working on this principle it has effected conquest of a large part of the material environment within reach, and shows every prospect of conquering much more. Whether pursuance of the same principle may lead to a knowledge of 'reality' is a question to which the answer is not yet even dimly perceptible. As Sir James Jeans has more than once emphasized, science in its present stage of development can be compared, for all its marvellous accomplishments, to the babe's first nebulous awareness of its surroundings. It may know many more pebbles than Newton, but it still knows little of the beach, and less of the ocean.

'Reality,' if it is to be discussed at all, must for the present be discussed as a philosophical problem, and the scientist as scientist need not adventure into such regions. For him a theory is merely a conceptual model of perceptual facts; it is, in the wise words of Sir J. J. Thomson, a tool rather than a creed. That should be a matter of satisfaction, for when the scientist looks around him at the monument he has erected, he might be forgiven if, of much other speculative thought, he murmured the sentiment of Omar Khayyám:

'Myself when young did eagerly frequent
Doctor and Saint, and heard great Argument
About it and about: but evermore
Came out by the same Door where in I went.'

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.R.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

Meteorites and some of the problems which they present

LORD RAYLEIGH

The ancient Egyptian, Assyrian, Sumerian and Hebrew names for iron all signify 'the metal from heaven,' thus indicating that the earliest known specimens of iron were of meteoric origin, and, further, that the fall of meteorites had been observed. Lord Rayleigh describes the two principal kinds of meteorites, namely those composed chiefly of iron and those of a stony nature, and offers experimental evidence bearing upon the origin of the rare intermediate type containing both iron and stone in roughly equal amounts.

The history of this subject is most instructive for the philosophy of discovery generally. The scientific movement of the seventeenth century which is associated with the foundation of the Royal Society, the Paris Academy of Science, and the Accadèmia del Cimento in Florence was in part directed to the impartial investigation of alleged marvels, to see what measure of truth there might be in them. Thus we learn that the Royal Society at one of its early meetings arranged some powder of the horn of a unicorn in a ring on the table and placed a spider inside, in order to observe whether it could get out. It did so without difficulty, and the supposed marvel was discredited by the evidence of experiment. (The unicorn's horn was probably a narwhal's tusk.)

The general experience of those who have examined marvellous stories with cold scientific scrutiny has been the same. The great majority of such stories break down under investigation. It is often difficult to understand how they arose, but there can be no doubt that a large proportion of untutored minds delight in the marvellous and are disposed to accept it very uncritically. The difficulty of finding out the exact truth about any physical happening is much underestimated. In particular, no clear distinction is made between what was observed and what was inferred. It is largely by relying on this intellectual weakness that the conjurer makes his living.

It would be too summary to say that these early inquiries into the marvellous always led to a negative result. Joseph Glanvil, for example, an early Fellow of the Royal Society, looked into the question of witchcraft, and arrived at the conclusion that the evidence in favour of the belief was overwhelming. There is no reason to doubt that he had made an honest attempt to arrive at the truth. On the whole, however, the result was usually to discredit marvellous stories; and by another very ordinary weakness of human nature, a premature generalization began to be formed that all such stories were untrue, and that it was a sign of mental superiority to reject them without examination. Considering the limitations of human life and effort, it can hardly be laid down that all alleged marvels deserve to be examined. In the last resort, individual judgment and inclination must decide: and most scientific men at the present time are not unwilling to examine into the marvellous if it comes their way. If they agree to do so, and if they see reason to reject it, they must be prepared to be considered perverse by the obstinately credulous.

Stories of the fall of stones from the sky were emphatically classed with the marvellous, in spite of the fact that numerous traditions of such occurrences existed, including some in the Bible, and others in the classical authors. There must have been an appreciable number of falls during the Middle Ages, but, owing to lack of facilities for travel, lack of interest in science, and possibly also a general belief that miracles more interesting and significant than this one occurred fairly often, the available data were not collected or systematized. Much more interest was taken in the spurious bone of a saint than in a stone which had really fallen from the sky. It was only when mediaeval conditions began to pass away that this state of things was changed. The earliest known specimen of a meteorite actually seen to fall is preserved in the parish church of Ensisheim in Alsace. It fell in 1492.

It was long, however, before the scientific world became convinced; and this was no doubt due to the sceptical bias which was a necessary condition for the birth of the scientific movement.

The French Academy of Science received in 1772 a report on a stone said to have fallen at Lucé a year or two before. Lavoisier was a member of the reporting committee. They considered that the stone was an ordinary stone which had been struck by lightning. It was not till many years later that the sceptics were finally silenced. A very large number of stones was reported to have fallen at L'Aigle in France on 26th April, 1803, and the Academy dispatched the well-known physicist Biot to investigate. His report finally settled the controversy, and he was even credited with the discovery, though it would be more correct to say that he broke away from the fashion of disbelief.

Once it is admitted that the falls actually occur, the question naturally arises: What is their real frequency? This is not an easy problem to resolve. In most places there is no one to observe a fall when it does occur, and it would evidently be most unsafe to attempt to estimate the probabilities of its being picked up afterwards. The only method which seems to give a reasonably trustworthy indication is to count the falls which actually occur on buildings, and then to estimate the fraction of the whole territory which these buildings cover. In this way it has been estimated that perhaps 250 falls occur in the United States per annum. No great reliance can be placed on this estimate, though it is probably of the right order of magnitude. Occasionally there have been falls of enormous meteorites which must have forced themselves on the attention of any observer who was within hundreds of miles of the spot. In various parts of the earth there are craters which are believed to mark the site of such falls (figure 1). Dr L. J. Spencer, formerly Keeper of Minerals in the British Museum, has devoted special attention to this subject, and has collected the available information. As might be expected, desert regions are favourable for the preservation of such craters, for in these regions the action of water and vegetation is at a minimum. If we recall how soon wasted areas in France and Belgium, covered with enormous shell-holes during 1914–18, recovered their normal aspect after a few years, we shall perhaps not be surprised that the meteor craters are only well discernible in areas where there is little water and little vegetation. The gigantic Siberian meteorite of June 1908, which fell at a distance of some 400 miles north-east of Lake Baikal and which produced a column of fire visible from 300 miles away, is perhaps the largest fall of which we have a dated record, but after a lapse of some twenty years it was found that the craters had largely fallen in and become filled up. In no case has a meteorite been located inside the crater, though in several instances numerous fragments have been found outside it. Mainly for this reason, Dr Spencer has urged the view that the crater results not directly from the impact, but from the explosion of steam or other vapours which result from the burial of the heated mass.

It has been suggested that the craters on the moon are of meteoric origin, and this view has found favour with some writers of authority. There is, however, an objection to it which I have not seen noticed. R. W. Wood has found that a region near the crater Aristarchus appears much darker when photographed through a screen transparent only to ultra-violet light (figure 2), and has come to the conclusion that this appearance is best explained by supposing that the rock is coated with a slight deposit of sublimed sulphur. Rock artificially treated in this way gives the same result. Sulphur is of course associated with volcanic activity, and the evidence seems rather strong that this particular crater, at any rate, is of volcanic rather than of meteoric origin.

But the questions have perhaps been too long delayed: What are the peculiarities of meteorites, and to what extent do they differ from materials normally found on the earth's surface or in mines? Can we distinguish a meteorite from all ordinary geological specimens?

A common delusion should first be cleared away. The heavy spherical balls occurring on the south coast of England, and found on fracture to possess a radiating structure of metallic aspect, are often popularly imagined to be 'meteorites.' They are nothing of the kind. These balls consist of marcasite, a form of iron sulphide, and occur embedded in the chalk cliffs where they originated. They are released by weathering, and in some places are quite common on the seashore at the base of the cliffs.

Of genuine meteorites there are two principal kinds, iron and stony meteorites; though, as we shall see presently, there is every intermediate gradation between these extreme types. The iron meteorites are far the commonest in museum collections, but there is reason to believe that in this respect the collections are by no means representative of Nature; for among falls actually recorded at the time of the occurrence, the stones

are much commoner than the irons. If a meteorite is seen to fall, it is of course dug up and examined with eager curiosity, and without regard to preconceptions as to what a meteorite ought to be like, so that no particular kind is specially favoured. But if a meteorite is identified as such by its own characteristics, it is obvious that any observer, whether specially skilled or not, is much more likely to notice a mass of iron as being something out of the ordinary than to draw the same conclusion about a piece of stone. The latter may perhaps not be very difficult to distinguish from the stones of the district; but these last are often quite varied, having been conveyed for long distances by geological agencies such as ice or water. Hence it would indeed be rash to jump to the conclusion that an unusual kind of stone was a meteorite. On the other hand, if we meet with a mass of iron identified in the first instance by its weight, its coldness to the touch, and its behaviour under the file, and not bearing signs of artificial origin, we shall not often be wrong in concluding that it is a meteorite, for terrestrial iron found as such on the earth's surface is of rare occurrence. There are indeed a few cases where masses of free iron have been found, which are judged not to be of meteoric origin. The most conspicuous example is provided by those which were found by N. A. E. Nordenskiöld, the famous explorer, who was the first to traverse the North-East Passage; the site was Ovifak, Disco Island, Greenland, and the most recent view is that these masses were reduced from sulphide of iron by the action of carbon originally derived from the coal measures. In general, however, the earth's surface is too damp a place for free iron to survive for long, and this is one of several reasons for thinking that, whatever the circumstances of origin of meteorites, water was absent from the scene.

There are various instances of meteoric iron having been used by primitive peoples who did not practise the reduction of this metal from its ores. The references in Homer to iron as a rare and precious substance are perhaps best explained in this way. Iron ore is abundant, and if the reduction were practised at all it is not apparent why the product should be so scarce. On the other hand, meteoric iron is a very scarce substance indeed, and even now, when the earth's surface has been more fully searched, it commands large prices from collectors.

Meteoric iron differs from terrestrial iron in some important respects. One of the most striking points is that meteorites, broadly speaking, consist of one single crystal even if the meteorite weighs tons. In this respect meteoric iron differs entirely from any samples of iron which have been produced in industry, though it is true that some other metals, e.g. aluminium, have been produced in large single crystals in the course of experimental study. When we speak of single crystals, there is no reference to the presence of external crystal faces. The external surface of an iron meteorite is in fact rough and of irregular outline. What is meant is that there is a general tactical order and regularity prevailing without major discontinuity throughout the whole mass.

It would, however, be wrong to suppose that there are no minor discontinuities. The specimens of iron meteorites preserved in museums usually have a flat face worked upon them, which has been polished and then etched with acid, according to the technique usually practised in metallurgical research. The etching reveals a very remarkable structure, coarse enough to be examined without the magnification usually necessary for industrial metals. This etching process gives much information about the crystalline character of the specimen, and the pattern usually prevails without change of orientation over the whole surface, even in the largest meteorite. That is the ground for saying that only one crystal is concerned. In many cases the mutual inclination of the bright bands revealed by the etching process indicates that they mark the traces of the octahedral planes of the crystal. The fact that they show up at all proves that the material is not homogeneous, and in fact the bright bands consist of an alloy called taenite, which is considerably richer in nickel than the material of the broader and darker bands, called kamacite (figure 4).

The way in which this structure—called the Widmanstätten structure—has originated presents problems of considerable interest. If the nickel–iron is heated to, say, 1,000° C and re-examined afterwards, the structure is found to have disappeared, and so far no one has succeeded in reproducing it on anything like the original scale. To do so would involve a migration of metal atoms along distances of one or two millimetres through the metal, with a certain crystallographic rearrangement, into the details of which we do not here enter, all this occurring at a moderate temperature. Such a process might be expected to be extremely slow. Attempts to reproduce the structure by slow cooling have been made, and

have produced something very like it on a microscopic scale. Not all metallurgists are convinced, however, that this is really the same thing, involving migration of the nickel. The present writer is hardly qualified to express an opinion on this point. Metallurgical laboratories are for the most part occupied with urgent commercial problems, and cannot afford to spend much effort on matters of purely scientific bearing; but undoubtedly there are interesting questions here awaiting solution.

Stony meteorites present some peculiarities not met with in terrestrial materials, but upon the whole these peculiarities are not very striking. Such meteorites are generally speaking of the same nature as ultrabasic terrestrial rocks, that is to say those terrestrial rocks which contain the minimum proportion of silica and the maximum of metallic oxides. Meteorites never show anything like the composition of granite, which contains so much silica that part of it segregates as quartz. No quartz is found in the stony meteorites. They approximate rather to those heavy terrestrial rocks called peridotites, which consist mostly of olivine, and which are probably much more abundant at great depths than they are at the earth's surface. However, the stony meteorites often show other features, rather suggesting the aggregation of angular fragments, and they also contain spherical bodies called chondrules, of sizes varying over a wide range—from a millimetre up to two or three centimetres. The smaller ones are more usual. The chondrules sometimes seem to be rather loosely enclosed, and can be picked out just as the currants can be picked out of a bun. There is nothing like them in terrestrial rocks, and it has often been thought that their more or less spherical form was probably produced by attrition; but under what circumstances is purely a matter of guesswork. The chondrules sometimes contain glassy matter, suggesting that they have been rapidly cooled. Their composition is not materially different from that of the meteorite generally.

Although we have dwelt on the iron and stony types of meteorite as representative, yet probably no meteorite is entirely free from metallic iron, nor are the irons altogether free from stony inclusions. The rather rare intermediate type of meteorite, in which iron and stone are present in about equal amounts, has always seemed to me to be specially interesting and intriguing. It is not closely comparable with any known terrestrial material, and to conceive the way in which it has originated presents obvious difficulties. These difficulties I believe to a great extent admit of solution, and we will now consider their problem at some length.

As we have seen, the stony meteorites, in spite of minor differences, are on the whole of the nature of igneous rocks of the ultrabasic kind. The iron meteorites are compact, and consist in most cases of one huge crystal. Moreover, the metallographic structure is of a kind which suggests secular cooling from a high temperature. We can therefore hardly escape from the conclusion that these materials have at one time been melted and have cooled very slowly. This is one of many reasons which indicate that the meteorites we examine have at one time formed part of a body of large dimensions, though as to the circumstances under which they became detached evidence is almost entirely lacking.

However, to return to the stone–iron meteorites. The most conspicuous and typical of these are called pallasites, after the eighteenth-century traveller Pallas, whose name is associated with a typical example. These consist of fragments of olivine contained in a network or sponge of nickel–iron. Sometimes the olivine fragments are single crystals so perfect in the symmetry of their development that they seem to have been grown under ideal conditions—as a crystal of alum may be grown in the laboratory, hanging from a thread and surrounded on all sides by the mother liquor, though with this difference, that the olivine crystals have the faces somewhat rounded. If we could suppose that melted nickel–iron could dissolve a siliceous material like olivine in the way that water dissolves alum, the appearance could be largely accounted for. But needless to say we cannot assume anything of the sort, and to me at least it appears that there are insuperable difficulties in supposing that the nickel–iron and the olivine have separated from an originally homogeneous liquid.

Moreover, the olivine in many other pallasites is of quite a different aspect. Instead of consisting of perfect individual crystals, it is in broken fragments. This is illustrated by the Imilac meteorite, of which a large mass can be seen—or rather could be seen in happier times—in the Natural History Museum (figure 3). In other cases again the olivine consists of rounded fragments, as in the Brenham pallasite (figure 5). Some authors have taken the view that these rounded fragments owe their shape to surface tension of the melted material. If drops of oil are suspended in dilute

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FIGURE 1 (*above*) – *Meteor crater, Arizona,* 4,150 *ft. wide,* 600 *ft. deep.*

FIGURE 2 (*below*) – *Comparative photographs of the moon (region near Aristarchus) by R. W. Wood. (Left): yellow light; (right): ultra-violet light. The dark patch is probably due to sulphur.*

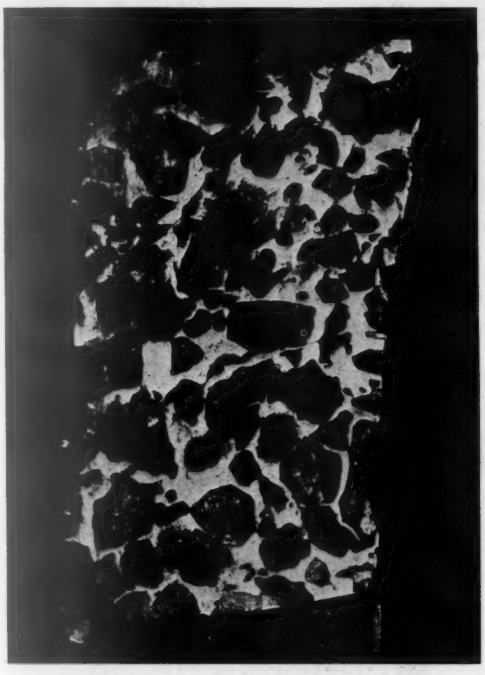
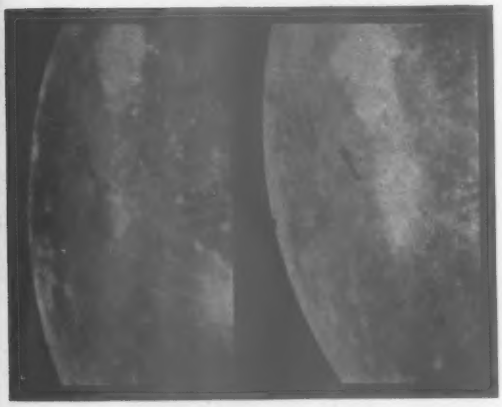


FIGURE 3 (*right*) – *Imilac pallasite, from a specimen in the possession of the author. Metal shows bright, olivine dark.*



alcohol of exactly the same density, they take a perfect spherical form, under the influence of surface tension, since this shape gives the surface of separation a smaller area than any other shape could do. The same cause makes a soap bubble spherical. It is true that the olivine is by no means of the same density as nickel–iron, but this difficulty must be faced in any case, for why did not the olivine all float up to the top? We shall return to this point presently. In the meantime the idea that the rounded shape is in any way due to drops is open to the objection that according to it the form ought always to be rounded, whereas in fact it is often conspicuously angular (see figure 3).

We find, in short, that some pallasites have more or less rounded olivine crystals, others rounded fragments without conspicuous crystal faces, and others again have conspicuously fragmental outlines. No theory which represents the olivine as having taken shape *in situ* in the iron mass can well cover all these cases, and for this and other reasons I prefer the view that they have taken shape quite independently, and have become immersed in the melted metal afterwards. Well-known natural processes will account for each of these shapes, the olivine crystals having been weathered out of a rock, the angular fragments produced by fracture, and the rounded ones by attrition. I thought at first that if the iron were melted the olivine would necessarily be melted also, and would form a layer on the top; but this is a mistake. The careful measurements

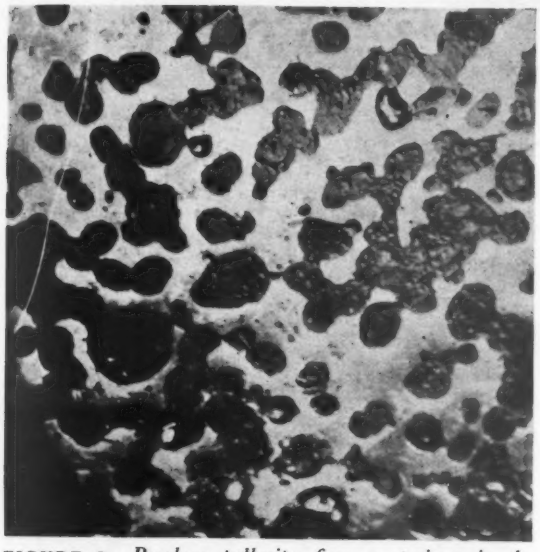


FIGURE 5 – *Brenham pallasite, from a specimen in the British Museum.*

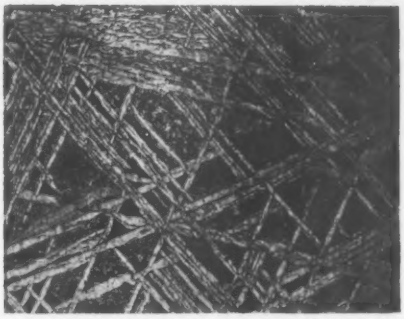


FIGURE 4 – *Widmanstätten structure: meteoric iron of Gibeon shower.* (*After Dr L. J. Spencer, F.R.S.*)

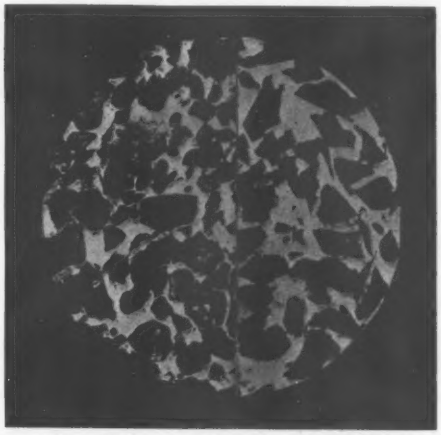


FIGURE 6 – (*left*): *Imilac meteorite;* (*right*): *synthetic imitation.*

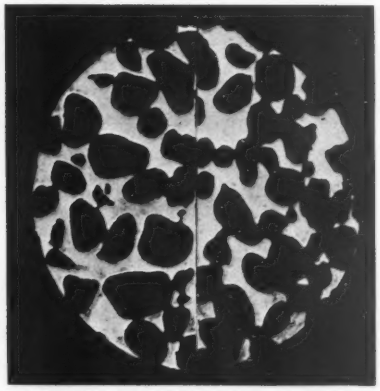


FIGURE 7 – (*left*): *Springwater pallasite;* (*right*): *synthetic imitation.*

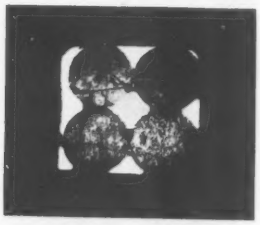


FIGURE 8 – *Steatite spheres immersed in solder and sectioned.*

of Bowen and Schairer have shown that the melting-point of olivine is nearer that of platinum than that of iron. There is no reason why a stratum of olivine fragments should not be engulfed by molten nickel–iron flowing in from below or from above, provided that the olivine were not free to float up. The necessary constraint to prevent this can be provided by the weight of material above lying on it.

This simple theory of the origin of pallasites has been tried out in experiment—not indeed by using iron and olivine, because these would require facilities for melting iron and for slicing the hard product which were not available. Resort was had to more tractable materials—steatite (soapstone) to represent the olivine and plumber's solder for the iron. The steatite fragments must be shaped according to the kind of pallasite we wish to imitate. They may be obtained by pounding up the material; or alternatively they may be rounded into pebbles by rolling them over and over in contact with one another, or

(in order to get on more quickly) with hard objects such as hexagon steel nuts. It is then only necessary to sift the fragments free from powder and fill them into a mould. The melted solder is poured in, and after cooling the mass is cut up into slices, so that the structure can be conveniently examined. It is found to be closely representative of the structure of the pallasites. Figure 6 represents a synthetic product of this kind in comparison with the Imilac meteorite. Figure 7 similarly compares a synthetic product made from rounded fragments with the Springwater pallasite. The reader will perhaps agree that a good artificial imitation has been secured.

Melted metals—e.g. mercury—do not in general wet stone surfaces, and in consequence the melted metal will not close into the space between two pebbles right up to the point of contact. This is shown in figure 8, which represents the section of four steatite spheres placed in contact, with solder poured round. The necks apparently separating the spheres are characterised by *absence* of metal. The same thing is seen in those pallasites which contain rounded olivines (see figures 5 and 7) as in the synthetic reproduction, and is thought to confirm the view here taken as to their mode of origin.

In this article it has only been possible to touch lightly on certain aspects of a subject which has very wide ramifications. In particular, the important subjects of the age of meteorites and their astronomical relations have been left untouched. It is hoped that the reader's interest may have been sufficiently aroused to lead him to study the original literature.

In conclusion, a topic of considerable interest in connection with meteorites may be mentioned. At various times within the recollection of the present writer, there have been important developments on the subject of silica glass. These began with the work of Sir C. V. Boys (1855–1944) as long ago as 1887. Boys was interested in the production of fibres which would serve for the torsion balance—fibres which would have the desirable property that the restoring torque called into play by a twist would not vary with time, but would always be proportional to the twist applied. The glass or silk fibres commonly employed in laboratories before Boys' time were far from this ideal, and he conceived the idea of melting various minerals in the oxygen blowpipe and drawing them out finely, to see whether they would yield fibres mechanically better than glass or silk. As is well known, the production of quartz fibres was the result. But when the way had thus been opened, it was natural to go further. Fused silica prepared for drawing quartz fibres was found to have remarkable qualities in another way—that is in its small thermal expansion, which makes it much less liable to crack by sudden or unequal heating than vitreous substances in general. A considerable industry has been developed as the result of this observation, and large vessels of fused sand or fused rock crystal are produced commercially and are important in the chemical and electrical industries, for example in making the containing vessels for the valves used in wireless transmission. Here, however, we are not primarily interested in these industrial developments, but in the unassisted operation of Nature. Lumps of fused silica have been found on the sandy surface of the Libyan desert, and so far no satisfactory explanation of their origin has been forthcoming. They have been presumably lying there on the sand for long periods—long, that is, as judged by historical rather than by geological standards. In former times the waterless regions in which the silica is found were practically inaccessible, but the motor-car has changed all that, and the locality has now become comparatively easy of access, apart from the difficulties incidental to war conditions. Dr Spencer has taken a special interest in the subject, and has visited the spot. I am indebted to him for some specimens.

The question now presses for answer: How did these specimens of silica glass come to be deposited on the sandy surface of the desert? It must be confessed that no clear and satisfying answer to this question can as yet be given. There is nothing to suggest that the locality where the silica glass is found has been the scene of any violent convulsion of Nature. There is no sign of igneous action of any kind. The lumps of silica, sometimes clear, sometimes translucent, lie on the desert sand, and there is no vestige of an explanation of how they came there. The area of desert over which they are scattered is much too large to allow us to connect them in any way with the activities of man, and indeed the character of the material itself is such as to make it certain that no explanation is to be found in this direction.

Since there is nothing in the local geology to afford the slightest hint as to how the silica glass came there, and since the material itself may be regarded as unique and unlike anything known to exist elsewhere on the earth's surface, some have thought that the easiest escape from the

difficulty is to assume that the silica glass fell from the sky. This hypothesis certainly cannot be disproved in the present state of knowledge. The appearance of the silica glass when it is actually found on the desert sand is admittedly difficult to explain on any alternative view. On the other hand, its chemical and mineralogical characters are very different indeed from those of recognized meteorites. We can but record the facts, acknowledging that they are difficult to fit into the framework of existing knowledge, and that they do not afford obvious clues for further research.

Museums

In a recent report[1] published by the British Association for the Advancement of Science, Dr A. S. Wittlin discusses the part of the museum in modern society. It is pointed out that the potentialities of the museum as an aid in education are considerable but have as yet hardly been tapped. Broadly speaking, the chief functions of the museum may be described as (i) the advancement of knowledge, or research, and (ii) the diffusion of knowledge, or education. Museums for the advancement of knowledge are collections forming parts of research institutions, and Dr Wittlin believes that fundamentally these are on the right lines. Museums for the diffusion of knowledge represent the majority of the museums of Europe, and on the whole must be regarded as badly lagging in development if compared with other institutions of modern society. This would seem to be due to the museum's insufficient contact with reality.

Among specific shortcomings of the average museum, Dr Wittlin lists incoherence of exhibits (a single room in one museum contained specimens representing sixteen different areas, six main periods of history, and more than twenty different subject-matters), monotony in selection and presentation of objects, overcrowding, architectural unsuitability, and lack of clarity in labelling. Many of these faults may be ascribed to the direct descent of the public museum from the private collection of the sixteenth to eighteenth centuries, but other factors, such as isolation and poverty, are partly responsible. In an additional note, Professor Sir John Myres remarks that every museum needs, for wholesome and efficient development, to be brought into direct and active relation with other scientific and cultural institutions of its locality—especially the libraries, which have the same double function of repository and illustration. Such close relation could be effected by representation on the museum's board of management, by arrangements for loans and exhibitions, and by provision of demonstrations or lecture courses at the museum. Active use of the collections in this and similar ways would bring deficiencies to the notice of those able to remedy them, and would call public attention to the museum's needs as a public and social institution. Further financial aid is necessary. The present standard of provision is too low, partly because the museum has been too often regarded as a storehouse for unwanted objects rather than as an aid to study.

For future development a prime requisite is the training of museum curators. Up to the present, no standards exist for the professional qualifications of curators, and Dr Wittlin suggests that the universities should take this matter in hand. He recommends a one-year post-graduate course, with a syllabus including such subjects as the history of civilization and of arts and crafts, the theory of education, the principles of psychology, and museum architecture, crafts, chemistry, and administration. Abbreviated courses might usefully be arranged for teachers and other educationalists wishing to use the museum as a method of teaching.

With trained curators available, the reorientation of museum policy could be systematically undertaken. Numerous technical problems await solution, but these are less important than the formulation of a definite programme of general aims. Man's consciousness of human capacities and of aspects of human society may be considered as a major requirement in present-day education, and the museum might clearly do as much in this direction as in the more traditional path of surveying material culture and the world of nature.

While the report thus sees much that is unsatisfactory in the present state of museums and museum policy, it notes that efforts have been, and are being, made to improve the situation.

[1] *Advanc. Sci.*, 1944, 3, 9.

The Royal Institution of Great Britain

THOMAS MARTIN

The Royal Institution of Great Britain, founded nearly 150 years ago by Benjamin Thompson, Count Rumford, has performed yeoman service to the cause of science and still happily continues its flourishing existence. Mr Thomas Martin, who has been General Secretary of the Institution for many years, provides a bird's-eye view of its history and points out that it has now become a centre of international scientific co-operation.

At the end of the eighteenth century one of the intellectual centres of London was the house in Soho Square of Sir Joseph Banks, the gouty and autocratic President of the Royal Society. No scientific enterprise could hope for success without the President's approval; and when Count Rumford launched his proposals for a new institution 'to facilitate the introduction of useful mechanical inventions' and to 'teach the application of science to the common purposes of life,' the first meeting was naturally held at Soho Square under Banks's chairmanship. The plan was adopted, and the Royal Institution of Great Britain was founded on 7th March, 1799.

FIGURE 1 – *Michael Faraday.*

Benjamin Thompson, Count Rumford, an American who had fought on the British side in the War of Independence, had recently returned to London after service as a high officer of state under the Elector of Bavaria. In Munich he had made his well-known experiments on the heat generated by friction in the boring of cannon, and had established a reputation for practical philanthropy and the administration of establishments for the poor. Pursuing his philanthropic interests in London, his new Institution was designed to introduce the benefits of science to the working people; while at the same time the higher ranks of society, to whom he looked for financial support, were to share the advantages by means of scientific lectures and experiments.

A house in Albemarle Street was taken, Rumford personally supervising every detail of the arrangements. He designed the famous lecture theatre himself. He drew up the constitution of the new body with its hereditary Proprietors and Committees of Managers and Visitors. He engaged professors—Thomas Young, of the wave theory of light, was one of the first. But his greatest contribution to the success of the Institution was made when he engaged a certain young Cornishman, Humphry Davy—who had become known for experiments on nitrous oxide—as lecturer in chemistry.

Davy's success was immediate. He had natural gifts of exposition, and all London flocked to Albemarle Street to hear him lecture. The new laboratories gave him opportunities for experiment, and before long he was launched on the career of discovery which made him the greatest chemist of his age. The chemical action of the electric current, the discovery of new elements (particularly sodium and potassium), the proof of the elementary nature of chlorine, and the invention of the miner's safety lamp are among the researches that brought fame to him and to the Institution in which he worked. He was knighted by the Prince Regent, was elected President of the Royal Society, and became the acknowledged leader of English science.

Humphry Davy established the great tradition of research and exposition which has ever since characterized the Royal Institution; but in doing so he altered the institution Rumford had planned. The school for mechanics, the exhibition of model stoves and appliances, and the demonstrations of cookery were dropped. The changes were recognized by Act of Parliament in 1810, which incidentally dispossessed the hereditary Proprietors

FIGURE 2 – *Benjamin Thompson, Count Rumford.*

FIGURE 3 – *Humphry Davy.*

and substituted for them a body of Members.

In 1813 Davy had engaged as assistant in the laboratory a young man, formerly a bookbinder's apprentice and the son of a blacksmith. The assistant was destined to succeed his master, and to rival or exceed him in scientific fame, for the blacksmith's son was none other than Michael Faraday. Soon he was appointed Superintendent of the House, and brought his young wife to live at the Institution; and when John Fuller endowed his professorships, Faraday became the first Fullerian Professor of Chemistry.

Faraday maintained and extended the tradition Davy had established. As an experimental lecturer he was without a rival, and those well-known features of the Institution's work, the Friday Evening Discourses and the Christmas Juvenile Lectures, owe their inception to him. The fame of his researches has become almost legendary. First a chemist, he discovered benzene, the foundation of the dye industry, and worked on alloy steels and optical glass. He liquefied chlorine. Turning his attention to electricity, the long series of experimental researches followed which have become the foundation of modern electrical science. The greatest of his discoveries, that of electro-magnetic induction, is the origin of the dynamo and the beginning of the generation and distribution of electric power in the service of man. Faraday's life and work have remained the spirit and inspiration of the institution he loved.

A succession of great men has followed Faraday. John Tyndall, lecturer, writer, experimenter, and mountaineer, succeeded him as Resident Professor. James Dewar's Friday Evening Lectures on liquid air are still remembered. In the laboratories Dewar first liquefied hydrogen. He invented the 'Thermos' or Dewar flask; and with his liquefied gases experimented at extremely low temperatures and originated the modern technique of refrigeration. Lord Rayleigh extracted argon from the gases of the atmosphere. In more recent years Sir William Bragg and those who worked with him have developed the new science of analysis of crystalline structure by means of X-rays.

Generations of men of science have found in the Royal Institution a source of encouragement and inspiration. In recent years it has been a centre of international co-operation and accord among scientific men—as at the Faraday celebrations in 1931. When war is ended and frontiers are opened again, the Institution will be ready to resume its functions and help in its own sphere to restore peace and friendship among the nations.

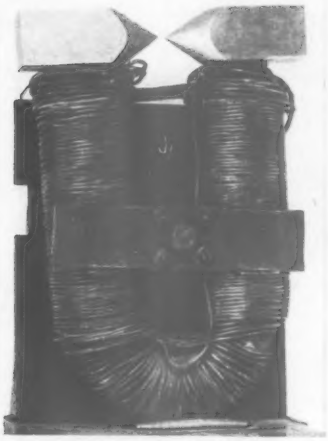


FIGURE 4 – *Faraday's great electromagnet.*

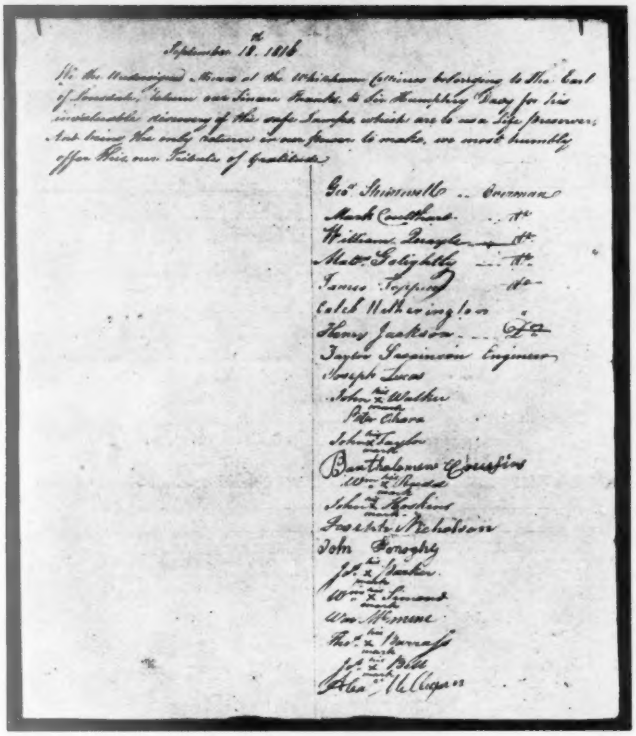

September 19. 1816
We the Undersigned Viewers at the Whitehaven Collieries belonging to the Earl of Lonsdale, Tender our sincere thanks to Sir Humphry Davy for his invaluable discovery of the safe Lamps which are to us a Safe preserver. And being the only Returns in our power to make, we most humbly offer this our Tribute of gratitude
Geo. Stevenson & Co ... Overman
Mark Coulthard ... Do.
William Dingle ... Do.
Matt. Golightly ... Do.
James Topping ... Do.
Caleb Wetherington ... Do.
Henry Jackson ... Do.
Taylor Jefferson Engineer
Joseph Lucas
John Walker
Peter Elwen
Richard Taylor
Bartholomew Cousins
Richard Rowland
Isaac Nicholson
John Doughty
Wm. Simons
Wm. Mennine
Thos. Mennine
Jos. Bell
John M'Cann

FIGURE 5 – *Miner's safety lamp. Letter conveying the thanks of the Whitehaven colliers to Davy.*

FIGURE 6 – *An early electrical machine by Nairne used at the Royal Institution.*

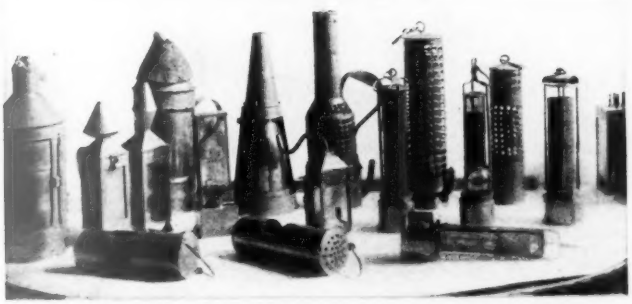


FIGURE 7 – *Miner's safety lamp. Experimental lamps used by Davy.*

FIGURE 8 – *Faraday's specific inductive capacity apparatus.*

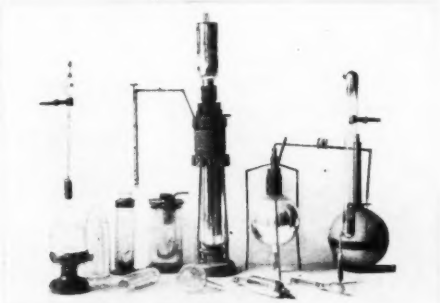


FIGURE 9 – *Dewar vacuum vessels.*

Mercer and mercerization

A. W. BALDWIN

Mercerization, like silhouette, has become so familiar a word that its derivation from a patronymic is apt to be overlooked; but John Mercer was as real as Etienne de Silhouette. A Lancashire man with a passion for chemistry, he thoroughly deserved the title of 'Father of Textile Chemistry.' His discoveries laid the foundation for the manufacture of highly lustred, or 'mercerized,' cotton; for the invention of viscose rayon; and for a process of making cuprammonium rayon.

A hundred years ago, in a village in Lancashire, England, a calico printer named John Mercer treated cotton with caustic soda and noted that its properties had been profoundly changed. This was the first step in a process for the transformation of cotton, a process which was to become known throughout the world as mercerization, and was perhaps the most important observation made in a lifetime devoted to pioneer investigation in the field of textile chemistry.

John Mercer was born in 1791 at Dean, in the parish of Great Harwood, near Blackburn, where his forbears had lived for several generations. In 1800 the early death of his father left his mother and her three children almost destitute, and young John, at the age of 9, commenced work as a bobbin-winder. It was during this period that he made his first contact with the Oakenshaw Print Works, which was to be associated with most of the discoveries he made throughout his life. An employee of this calico-printing firm, a pattern designer named Blenkinsop, took the trouble in his spare time to teach a very earnest and obviously able child the first principles of reading, writing, and arithmetic. This was the only schooling or training of any kind bestowed upon one who was to become ultimately a Fellow of the Royal Society, a reader of papers to the British Association, and an associate of the nineteenth-century giants of British scientific philosophy. The seeds of Blenkinsop's teaching fell upon most fertile soil, however, for it soon became apparent to the more intellectual of the local worthies that the boy Mercer had a most remarkable flair for learning, and particularly for mathematics.

Mercer's first introduction to the art of dyeing was in 1807 when, as a youth of 16, he visited his mother, who had married again. He was so fascinated by the bright orange colour of a frock worn by a child step-brother that he became obsessed with a determination to learn dyeing. He proceeded by the only possible route for one in his position. He sought and found the druggist in Blackburn who supplied the local dyers, and bought small samples of everything needed for dyeing—brazilwood, logwood, quercitron, alum, copperas, etc.—to the tune of a total expenditure of half a crown. He took his purchases home and began to experiment.

His experiments were so successful that he set up in a small way as a dyer, in partnership with a friend, and in less than a year was acquiring a local reputation. He was soon persuaded, however, by Mr. Fort of the Oakenshaw Print Works, to give this up and to apprentice himself to the older and established firm. The opportunity to extend his knowledge more rapidly, aided by professional guidance, was too good to miss, but unfortunately the new job did not work out quite as he had hoped. About this time the Oakenshaw Print Works entered a period of hard times brought on by the Berlin Decrees[1], and when they offered to release apprentices from their obligations Mercer, who had been constantly frustrated by a foreman who frankly considered him an upstart and an aimless meddler, took the opportunity to leave. He returned for a livelihood to hand-loom weaving, a craft he had learned as a boy.

A few years later, as was inevitable with such a man, he resumed his amateur dabbling in dyeing, an appropriate prelude to a chance event which was to influence the whole of his life. Whilst browsing in a second-hand bookshop in Blackburn, actually a few days before he married, he picked up a copy of *The Chemical Pocket Book*, by James Parkinson of Hoxton. This revealed an entirely new and fascinating world to him, a

[1]The Berlin Decrees were Napoleonic edicts which ordered, *inter alia*, the confiscation of all British merchandise on the continent of Europe.

FIGURE 1 – JOHN MERCER, F.R.S.
1791–1866

world which he quickly realized to be of prime importance to the dyer and printer. No sooner had he begun to study, or rather devour, this book than he started to experiment on the basis of his reading, for that was always Mercer's way. Phenomena recorded in a book had to be witnessed on the bench; any theory which occurred to him promptly became the subject of laboratory trials by whatever means he could devise. His initial study of Parkinson bore early fruit, and he was soon able to develop novel printing effects by the application of simple inorganic chemistry. Hearing of these discoveries, Mr. Fort asked him to rejoin the Oakenshaw Print Works, but this time as a chemist—at a salary of thirty shillings a week!

This fresh start, which was undertaken without any reproaches for the shabby treatment he had received earlier, was the real outset of Mercer's career. Eagerly seizing the more adequate

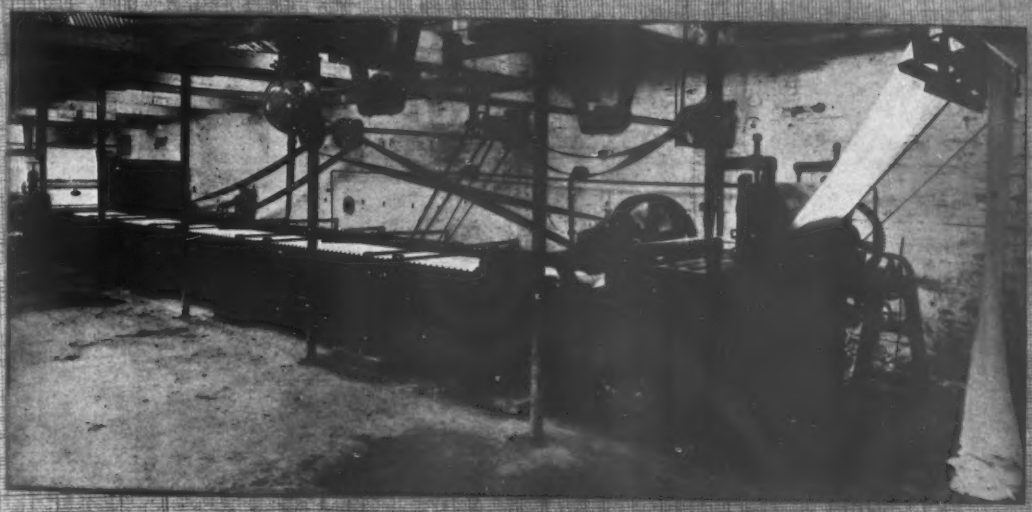


FIGURE 2 – *One of the first complete machines for mercerizing cloth continuously in the piece. Installed about 1898. Photograph taken from the delivery end.*

FIGURE 3 – *Another early machine, installed about 1900. Photograph taken from the entering end.*

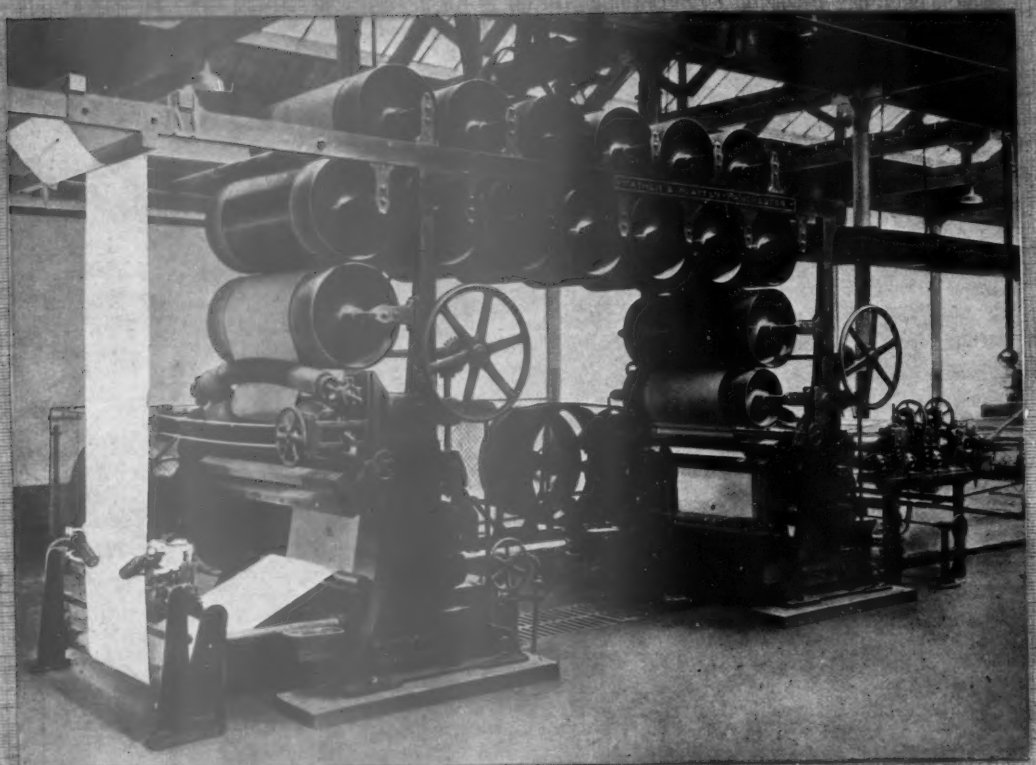


FIGURE 4 – *This is one of the most recent and up-to-date mercerizing ranges installed in England, showing the two three-bowl impregnating mangles with intermediate sheet-iron drums for impregnating the cloth with caustic soda before stretching on the stenter.*

FIGURE 5 – *Another view of the same machine taken from the delivery end.*

FIGURE 6 – *This is a mercerizing range for cloth 100 in. wide, and is probably the largest and most powerful machine of its kind in the world.*

(*The photographs of mercerizing ranges by courtesy of Mather and Platt Limited*)

laboratory facilities available to him, he embarked upon investigations which were to leave their mark on the trades of dyeing, printing, and finishing textiles. There is little doubt that any chemist of average competence would have effected profound changes in these trades, for in the eighteen-forties they were ripe for the introduction of chemical method as a change from guesswork. Mercer was on the spot, however, employed in the very heart of the industry instead of in a university laboratory. It thus fell to him to show the benefits immediately to be gathered by the purification of raw materials, by analysis, leading to correct measurement, by control of temperature, and, consequently, by general standardization of operations. In seven years he had set his firm on the high road to prosperity, and at the end of this period he was rewarded by being taken into partnership.

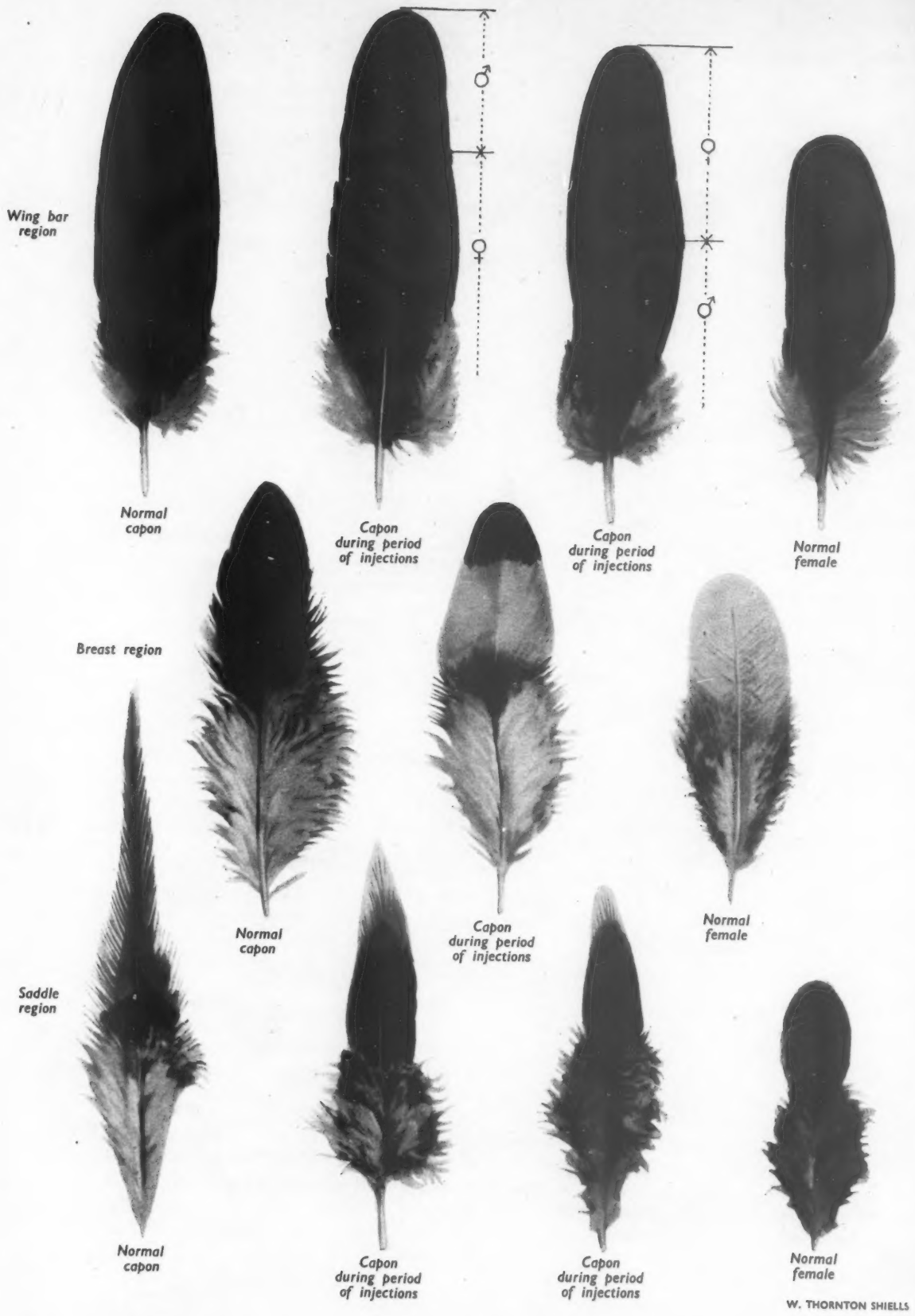
Mercer was indeed entering upon his most

fruitful period, and his activities went much further than merely standardizing dyeing processes. Apart from having a methodical and tidy mind, he had an extremely lively imagination and was a most prolific inventor. Here, however, it becomes necessary to divide his achievements into two broad classes: those which immediately concerned dyeing and calico printing and which rapidly found expression in the sales of his company, and those which called for development in wider fields where, unhappily, pioneers of similar calibre were not available or, at least, were not in touch with Mercer's work. On the one hand, the production of new yellow print effects by the precipitation of antimony sulphide on the fabric, the discovery of a new method of fixing Prussian Blue, and the substitution of a phosphate together with a glutinous material, carrageen, for the old-established dunging process, were promptly applied industrially, as this lay in his own hands. Similar success awaited many other technical devices, too numerous to mention here. A case in point, however, arose in the printing of delaines. To get the wool to print as readily as the cotton, Mercer chlorinated it. The effect on the printing world of this entirely novel operation was commercially gratifying, but there was nobody at hand to follow up the work, by investigating other effects of the process, and it was not until sixty years later that the non-shrinking properties of such chlorinated wool were realized. Again, as part of a method for improving the printing of Turkey Red he evolved a new product by the sulphonation of olive oil, but the wider application of this reaction, which pointed the way to the manufacture of Turkey Red Oil and the modern detergents and wetting agents, was not investigated until considerably later.

The most noteworthy example of such delay, however, was in the work mentioned at the beginning of this paper. In 1844 Mercer was carrying out research which had been inspired by certain experiments of Graham's; he was particularly interested in the formation of hydrates in solution. With a view to measuring viscosity and mobility of solutions, he passed caustic liquor through cotton linters. The interesting results which he observed in preliminary fashion had to be set aside, owing to the pressure of the firm's business and, later, to a severe illness. On his return to work, however, he took up the study of this 'fulled cotton' at the first opportunity. He found that he had increased the tensile strength of the cotton, increased its weight by about 5 per cent., and imparted to it a much higher affinity for dyestuffs. When he applied the caustic soda to cotton in printing styles he got an interesting crêpe finish and a further novel effect by after-dyeing. Shortly after this work he found that he could swell cotton by treating it with sulphuric acid and zinc chloride solutions, and observed, as also did Schweizer independently, that cellulose could be dissolved in a solution of copper oxide in ammonia. All these observations had been made by 1850, and were fully recorded, but very little came of them for over forty years. The main reaction from a conservative cotton trade was that Mercer had succeeded in shrinking cotton, an undesirable effect for which there was no market. Yet he had laid the foundation for the highly lustred cotton, now known as mercerized cotton, produced in 1890 by Lowe, who carried out the caustic treatment under conditions that prevented shrinking and thereby set up lustre; for the invention of the viscose rayon process by Cross, Bevan, and Beadle in 1892; and for the Bemberg process of manufacturing cuprammonium rayon. The more modern plastics industry, requiring a variety of cellulose derivatives which need to be prepared from soda cellulose or alkali-activated cellulose, owes a great deal to these early investigations.

Mercer always displayed a deep interest in theoretical chemistry. He formed a discussion group at Whalley, a nearby village, where he propounded his views on catalysis, the phenomena of chemical combination, affinity, and many other topics; and he was in frequent correspondence with Graham, Playfair, and other great chemists in Britain. Throughout all, however, he remained primarily a bench worker, quick to test theory by experiment, to tackle problems resolutely as he met them, and to follow them up as far as he could, no matter where they led him. Observations of the photochemical reactions of certain inorganic salts led him to devise novel photographic printing processes on paper and on cambric in a variety of colours; these he described in a paper to the British Association at Leeds in 1858 and exhibited to the Photographic Society of Vienna. Following an investigation of a complaint from a South American customer concerning the mildewing of some printed calicoes, a problem to which he found a technical solution, he went on to speculate about moulds and bacteriological growth. This latter was characteristic of the lively interest Mercer displayed,

(*Continued on page* 149)


Wing bar region
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Saddle region
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Normal female
W. THORNTON SHIELLS

Synthetic oestrogens

E. C. DODDS

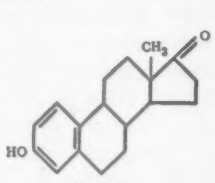
Substances secreted by the ovaries control the female sexual cycle. They are known as oestrogens, and their chemical constitution has been elucidated. Within the last few years substances more powerful than the natural oestrogenic bodies have been synthesized, and have been used clinically with remarkable results: e.g. in the relief of symptoms associated with the climacteric and the termination of lactation in women, and in the treatment of cancer of the prostate. They form a group of potent drugs of great interest and promise.

It is unusual for investigations which at first sight appear to be solely academic to produce important practical results in a relatively short time. That this has been the case with synthetic oestrogens will become apparent as the present article develops. Only recently quite unexpected uses of these substances have been brought to light, particularly in the treatment and control of one form of cancer. It will be necessary to give a very brief review of the naturally occurring oestrogens before we can enter into a consideration of the artificial or synthetic substances.

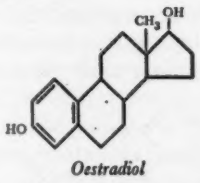
That the female sexual cycle and functions were associated with the ovary has been known from time immemorial; and since the development of the idea of internal secretions towards the end of the last century it has been recognized that the ovaries act by producing a substance which, entering the blood-stream, reaches the reproductive tissues and produces the characteristic cyclical changes of the adult female. It was only natural that organic and bio-chemists should try to isolate this active principle from the ovary. Years of careful work were handicapped by lack of a suitable quantitative biological test. This was introduced in the 1920s by Stockard and Papanicolou.

Working with small rodents such as rats and mice, they showed that there were certain characteristic alterations in the cells of the reproductive tract at a certain stage of their sexual cycle, and that this could be demonstrated in smears of the reproductive passage. If the ovaries were removed the alteration in the cells ceased, but could be restarted by the injection of an active substance into the castrated rodent. This fundamental observation was made by Allen and Doisy. Extensive chemical work was undertaken, but little progress was made other than to say that the substance was of a fatty type, soluble in organic solvents and containing only carbon, hydrogen, and oxygen. As extracted from the ovary, however, it was found to be unpurifiable by the methods then available, and the best preparation consisted of a sticky oil of unknown constitution. The turning-point came in 1927, when Aschheim and Zondek made the truly remarkable observation that the urine of pregnant women and animals contained very large amounts of this female sex hormone or oestrogen. Moreover, it was shown that the substance present in the urine, when obtained by extraction with volatile solvents such as benzene or chloroform, was in a much purer state than that obtained from the ovary. This discovery gave an entirely new impetus to the whole subject. In a relatively short time a number of chemists and bio-chemists (Marrian in England, Doisy in the United States, and Butenandt in Germany) had obtained crystalline products, and by a series of intensive chemical investigations in various parts of Europe and America the constitution of the oestrogenic substance was elucidated.

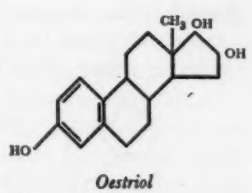
It was found that there were three main oestrogenic substances—oestrone, oestradiol, and oestriol; their structure is shown by the following formulae:



Oestrone



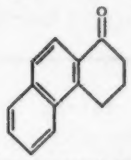
Oestradiol



Oestriol

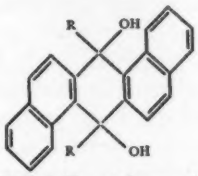
This was fully established by 1932 and is the starting-point of the investigations forming the main part of this article. The substances all have the same basic skeleton, but differ in the distribution of

their hydroxyl and ketone groups. Together with Cook and Hewitt, the writer decided to investigate how specific were the demands of the body for an oestrogenic substance, seeing that at least three were produced in nature. Very numerous derivatives of phenanthrene were prepared as a start and were tested on ovariectomized rats. It was quickly shown that the substance 1–keto–1 : 2 : 3 : 4–tetrahydrophenanthrene produced



1–keto–1 : 2 : 3 : 4 :–tetrahydrophenanthrene

the same qualitative results as did the injection of any of the three naturally occurring substances. There was, however, a great quantitative difference. Whereas as little as one to two thousandths of a milligram of oestrone was required to produce changes in a rat, as much as 100 mg. of the simple phenanthrene derivative was necessary for the same purpose. A series of other compounds was obtained by the same workers, and one of the dialkyldibenzanthracene diols, whose general formula is shown below, was found



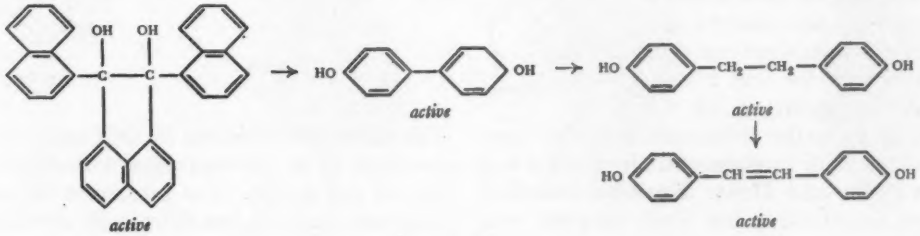
Dialkyl-dibenzanthracene diols

to be very highly active—although this was definitely the exception. The work, however, looked encouraging when it was shown that all the effects of the naturally occurring hormones could be reproduced. As an example the writer, together with Greenwood, showed that when injected into capons these compounds were capable of producing the same characteristic feminizing effect on the plumage as do the natural oestrogens. This is well indicated in the coloured reproduction (p. 144). On the left of the illustration are feathers of the normal capon, which are masculine. On the extreme right are feathers of the normal female, and in the middle are seen feathers modified by an injection of synthetic oestrogens. It is at once apparent that the injection produces an immediate feminization of the feather, which reverts to its male character after the injection has been terminated. Up to this point all the compounds possessed the phenanthrene ring system, and the next step was to determine whether this structure was essential for oestrogenic action.

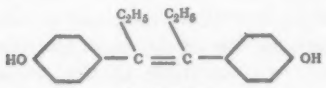
The writer, together with Lawson, investigated the activity of a number of compounds in which only two rings were fused, and obtained positive results with some of these. Still further simplification of the molecule necessary for oestrogenic action was attempted. The series of formulae at the foot of the page shows the various stages through which the investigation proceeded. It can be seen that we finished up in this series with the second relatively simple substance 4 : 4′–dihydroxystilbene or dihydroxydiphenylethylene. The parent hydrocarbon stilbene or diphenylethylene possesses activity, and this series has been developed by Robson and his co-workers. These substances are of much lower activity than those about to be described, but some of the earlier ones possess remarkable properties in that a single administration is capable of acting over a very long period. It must again be emphasized that this substance possessed only a fraction of the quantitative activity of the naturally occurring hormones.

Anol

An attempt was made to simplify the molecule still further by dropping off, so to speak, one of the benzene rings of 4 : 4′–dihydroxystilbene and substituting a methyl group for it. This substance, anol, was obtained by demethylation of anethole, a naturally occurring product which is the methyl ether of the substance required. This reaction was accomplished by heating anethole with

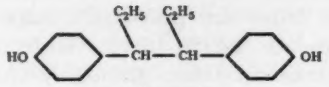


alkali and alcohol under high pressure in an autoclave. The resulting phenol was separated and crystallized, and was found on injection into ovariectomized rats to possess a very high degree of activity. Attempts to repeat this observation, however, showed an alarming discrepancy in the activity between the various batches of anol, and it became obvious that a serious error had crept into the work. Several anol batches were compared and their activity was found to vary from that of a very high order down to practical inactivity. A study of the chemical properties of anol revealed that it very rapidly polymerized, and we came to the conclusion that the activity was probably represented by a polymer formed during the demethylation of the original anethole. This view was supported by the observation that the mother liquor from which the phenol was crystallized always contained a high degree of activity. When concentrated, the mother liquor yielded a glassy mass which had a fairly high oestrogenic activity, but out of which in the first instance it appeared impossible to obtain a pure crystalline compound. A review of the situation led us to believe that the activity was a polymeride of anol and that on theoretical grounds it was likely to be a dimeride. The obvious next step, therefore, was to synthesize every possible dimeride of anol. On general principles it might be guessed that the active one would be the symmetrical dimeride. In the meantime, an investigation had been begun at Oxford by Sir Robert Robinson to prepare possible oestrogenic agents bearing a close structural resemblance to oestradiol, and it was decided to join forces. The synthesis of the symmetrical dimeride 4 : 4′–dihydroxydiethylstilbene was eventually accomplished, and this substance was found to be of astonishing potency. It has the following formula:



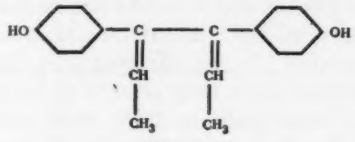
Stilboestrol

Its quantitative activity as compared with oestrone showed that it was roughly two and a half times as powerful; it could therefore have been a possible contaminant of the original anol. The development of this substance, which we eventually termed 'diethylstilboestrol' and which is now known as 'stilboestrol,' was a great practical step forward, but it was felt that stilboestrol was not sufficiently active to explain the potency of certain samples of anol. A determined attempt was made, therefore, to separate the contaminating substance from the mother liquor of the anol crystallization, and with the collaboration of Campbell this was eventually accomplished. The compound was shown to be closely related to stilboestrol and to differ from it only in the fact that the double bond between the α and β carbon atoms was hydrogenated. The same substance can also be prepared by the catalytic hydrogenation of stilboestrol. It was finally called 'hexoestrol' and has the following formula:



Hexoestrol

A further variant was obtained by an entirely different synthetic route, and this possessed double bonds in the side-chains attached to the central carbon atoms; it was known as the hexadiene compound and later as 'dienoestrol.'

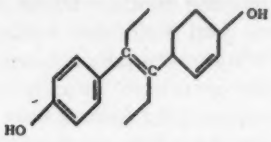


Dienoestrol

We have therefore three substances—stilboestrol, hexoestrol, and dienoestrol—all more powerful quantitatively than the naturally occurring hormone, yet bearing only a superficial resemblance to it in structure. These substances present fascinating problems from every point of view. First, from the stereochemical aspect there are two possible stilboestrols—the *cis* and the *trans* forms. These have been isolated, and we know that the more active compound, and the one at present used in clinical medicine, is the *trans* variety. In the case of hexoestrol we know that the substance used in clinical work is the *meso* or internally compensated compound, hexoestrol having two asymmetric carbon atoms. The isomers of dienoestrol have not yet been fully investigated.

From the biological point of view the interest in these substances is obviously very great. They can replace in every way the naturally occurring substances, and as already pointed out their resemblance from the structural point of view is only very slight. It is possible to write the formula of the *trans*-stilboestrol in such a way that it does apparently bear a relationship to the naturally

occurring oestradiol, as shown in the following diagram. It is difficult to express the activity of



the three principal synthetic oestrogens in terms of oestrone and oestradiol, but in a general way it may be said to be between two to five times as active. The great difference between the synthetic substances and the natural hormones is that whilst the latter are practically inactive when given by mouth, except in very large doses, the three synthetic substances are highly active when so administered; dienoestrol is probably the most active. Again, these synthetic substances are very cheap to produce and have given the experimental biologist and clinician an entirely new weapon for research. During the last six years many hundreds of papers have appeared in British and overseas journals as to their pharmacological and biological effects, and it would not be possible to review here all the various uses to which they have been put. To the clinician they are of the utmost interest since they present an inexpensive method of supplying the body with oestrogens; they therefore find employment in all cases where the naturally occurring hormones were previously employed. They have two outstanding advantages as compared with the natural hormones in that (i) they cost very little indeed; (ii) they can be given by mouth. The clinical employment of the naturally occurring hormones necessitated either subcutaneous or intramuscular injection, thus limiting their use to persons who could employ a doctor or alternatively attend at a clinic. Today, synthetic hormones are given in very large quantities to out-patients of hospitals.

The clinical application of the substances is extremely wide. It will perhaps be sufficient to give two of the main uses. Perhaps the most outstanding value is in the treatment of the distressing symptoms associated with the change of life in women. There now exists a large body of literature to show that in practically all cases this trying and difficult period can be completely relieved by the daily administration of a few milligrams of this substance in the form of pills. The vasomotor symptoms such as hot flushes, and the unfortunate mental instability which is associated with this period, and which causes so much human suffering, can be completely abolished in practically all cases.

The second great use is in the termination of lactation on weaning a breast-fed baby. This period is again known to be one of the most trying from the patient's point of view, attended as it is with acute pain and anxiety, and in some cases with actual infection requiring surgical intervention. The administration by mouth of an adequate quantity of the synthetic oestrogen terminates the secretion of milk abruptly and without any secondary effects.

In a certain percentage of cases slight nausea and side reactions are experienced in the early stages of the administration of synthetic oestrogens. This is said to be most noticeable with stilboestrol and least with dienoestrol, hexoestrol occupying an intermediate position. These symptoms, however, are really insufficiently serious to preclude the use of the compounds, and in most cases are entirely absent. It may be noted that the nausea is of central origin and probably has the same origin as the vomiting and nausea of pregnancy, as it is during early pregnancy that the body is flooded suddenly with an excess of oestrogen.

In addition to these two main indications, the synthetic oestrogens have also been used in other conditions in which the naturally occurring hormones have been insufficient, and they therefore play an important part in many types of gynaecological therapy.

At the beginning of this article attention was called to the fact that rarely does an academic investigation lead to immediate practical results. The foregoing paragraphs have shown that the synthetic oestrogens are exceptions. An entirely unforeseen and particularly fortunate use for these compounds has emerged from recent work. One form of cancer can now be controlled and the patient rendered symptom-free for periods as long as the treatment has been available—namely some three to four years. Cancer of the prostate gland is perhaps one of the most terrible forms of this disease. In addition to the usual ghastly progress, such as the formation of secondary deposits with pressure on nerves and intractable pain, this particular form of cancer is associated in its quite early stages with obstruction of the urinary outflow and all the horrors and suffering associated with it. The Chicago surgeon Huggins, for reasons which it is not possible to describe here, decided that if the activity of the testes could be overcome by castration or any other method, the relief of prostatic carcinoma symptoms might be obtained. It had been shown

previously that large doses of oestrogens inhibited the anterior lobe of the pituitary and that this produced a castration effect. After a long series of experiments, he eventually tried the effect of stilboestrol given by mouth. The effects were very encouraging and in many cases dramatic. We already have experience of numbers of patients treated in this country who have been rendered symptom-free, and maintained in a healthy condition whereby they can return to work. Not only are the local urinary disturbances completely relieved, but the extension of the secondary deposits appears to be inhibited and may even show some shrinkage; thus intractable pain due to pressure on nerves, and of a severity requiring morphia, has entirely disappeared. Even those cases showing pressure on the spinal cord have been completely relieved.

Whilst the results are unique in that it is the first occasion that any form of cancer has been controlled by a medicine administered by the oral route, it is only natural that the greatest caution should be observed in the interpretation of these results. The length of time that the treatment has been available is too short for us to say whether the relief can be maintained indefinitely, and under no circumstances can the treatment be regarded as a cure. That it is most encouraging, however, there can be no doubt.

With further experimentation, it may be that the synthetic oestrogens will find extending fields of usefulness; but even if they do not proceed any further, they certainly form a particularly interesting group of new, highly potent drugs, with much future promise.

REFERENCES

[1] ALLEN, E.; DANFORTH, C. H.; and DOISY, E. A. (editors). *Sex and Internal Secretions*, 2nd ed., 1939. (Baltimore: Williams & Wilkins.)

[2] DODDS, E. C. "The New Oestrogens," *Edinb. med. J.*, 1941, **48**, 1.

Mercer and mercerization

(*Continued from page 143*)

over a period of years, in medicine and in the medical application of chemistry. In the year 1848 his prompt and liberal application of bleaching powder was considered to have halted the spread of cholera in his district when four deaths occurred in a neighbouring village. While it cannot be said that he made any fundamentally important contributions to the knowledge of these several subjects, the examples quoted provide ample evidence of an extraordinary breadth of outlook.

By 1850 Mercer had achieved recognition, and indeed distinction, in academic circles. In 1852 he was elected to Fellowship of the Royal Society, but not without some persuasion—his natural modesty deterred him from joining such august company. He was elected a Juror in each of the two great International Exhibitions of 1851 and 1862. At the former, Queen Victoria was graciously pleased to accept a gift of cotton handkerchiefs which had been printed by Mercer's novel alkali process.

Mercer has been styled the 'Father of Textile Chemistry' and the 'Self-taught Chemical Philosopher,' but a truer picture would show him as a typical Lancashire man with a passion for chemistry. He died in 1866 in the surroundings in which he had lived, and was buried in the church of St. Bartholomew, Great Harwood, Lancashire.

REFERENCES

[1] MARSH, J. T. *Mercerizing* (Chapman & Hall Limited).

[2] PARNELL, E. A. *The Life and Labours of John Mercer, F.R.S., F.C.S.* (Longmans, Green & Company Limited).

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The trend of British veterinary parasitology

E. L. TAYLOR

In Great Britain, the most economically important parasites of domestic animals are the helminths. British veterinary parasitology is therefore primarily concerned with helminthology, and Dr Taylor describes recent work in this field. When the rationale of anthelminthic action is better understood, it will be possible to apply chemotherapeutic methods to full advantage, and thus to establish a firmer control over the parasites than is as yet practicable. At present their eradication appears to be quite out of the question.

It is a surprising thought that most of the living things in the world are parasites; but it is even more surprising to learn that the *species* of parasites are also more numerous than the species of hosts on which they live. Many kinds of animals and plants have several parasite species peculiar to themselves, and most parasites are strictly limited to a small group of hosts, so that the complete field of operations open to the student of general parasitology is a very large one indeed.

Veterinary parasitology as a subdivision of this field might be thought to concern itself with all the parasites of domestic animals; and no doubt this was so while the knowledge available to the early naturalists remained within the compass of a single human brain. The piling up of information has necessitated a subdivision of the work, however, and a research department of veterinary parasitology, or a book on the subject, may now be expected to deal primarily with helminthology, probably also with protozoology, perhaps with entomology as well; it may even deal with mycology, but it will certainly not deal with either bacteriology or the study of viruses.

In all its branches the growth of parasitology has followed the same general lines: firstly, a study of the morphology of the parasites and their classification; secondly, a study of their life-histories; and thirdly, their association with disease. In so far as the parasites of veterinary interest are concerned, the most useful work of the morphologist and systematist is now complete, as is also the work on the outline of life-histories, which, with few exceptions, is adequate to explain the origin of infection.

This important preliminary work is, in some respects, outside the veterinarian's field of activities. It is more proper to the biological laboratory, concerning, as it does, the structure and ordinary life of creatures which only under exceptional conditions are responsible for disease. A conventional subdivision into 'normal parasitology' and 'pathological parasitology' is a good one. It helps to define the special province of the medical or veterinary investigator, whose main object, whatever means he may employ, is the understanding of disease.

By far the most economically important parasites in Great Britain are the helminths, and the story of parasitic disease in Britain largely centres round the derangement of the ecological balance between these parasites and their hosts. This derangement has been occasioned by various agricultural developments, chiefly concerning the improvement of pastures and the increased concentration of stock. Some half-dozen helminth species and closely related groups of species are principally concerned, and the three main lines of research are (1) a minute study of the bionomics of the parasite in its life outside the mammalian host, (2) a study of the mutual reactions of the mammalian host and its parasitic community, and (3) the investigation of the parasiticidal treatment of the affected host.

As yet, eradication of these parasites appears to be quite out of the question. They occur wherever our grazing animals are kept, and the only practical objective for our present endeavours to prevent disease must be the control of parasite multiplication and the maintenance of their numbers at the normal ecological level.

The study of the bionomics of the free-living larvae of the nematode parasites of grazing animals has done much to improve our understanding of the epidemiology of the diseases which they cause. These investigations are now being extended from the laboratory into the field, and more direct epidemiological studies are being

made, with advantage, at the actual places where the diseases occur. Some interesting information, for instance, has recently resulted from a technique developed for the estimation of the numbers of infective nematode larvae in pasture herbage, and it has been surprising to find what large numbers are ingested daily by the grazing animal. A heavily infected sheep pasture, on which, however, the grazing lambs still show no outward sign of disease, may carry some 400 parasitic nematode larvae per pound of herbage; and as sheep, while grazing, eat some 15 to 20 lb. of herbage daily they must as the same time ingest about 8,000 young parasites. The percentage of the larvae which develops in young and susceptible lambs is high, and the parasites reach maturity in less than three weeks. Their potential life is relatively long, and as some 40,000 or 50,000 are sufficient to cause death, the importance of the resistance to parasitic invasion that develops in the grazing animal is clear.

The observations on the high rate of larval intake by animals at pasture also emphasize the benefit to be derived through the grazing of heavily infected herbage by an insusceptible kind of stock. The larval worms are too hardy to be injured by top-dressings of lime, salt, or other substances unless these are applied in large amounts, such as would at the same time destroy the grass. Ploughing does not dispose of them since they migrate to the surface again, so that alternate grazing by insusceptible stock appears to be the only quick way of reducing the infection of the field. Hence, hard grazing with sheep or cattle is of great benefit to horse pasture; the thousands or tens of thousands of larvae which are collected daily by each individual sheep or cow are destroyed, and the pasture is rendered relatively clean.

In addition to the grazing by stock of a species differing from that which had been responsible for the infection of the ground, adults of the same kind may similarly be used to clean the pasture for the younger animals, as their resistance is comparatively great, and the larvae which they ingest are destroyed.

The application of the technique for the recovery of larvae from pasture herbage shows the benefit that may also result from grazing adult and young animals together. It is found, for instance, that towards the end of the summer lambs which appear to be healthy may be passing as many as 9,000 eggs per gram of faeces. Supposing thay they void some 900 gm. of faeces daily, then the daily output of eggs will be some 8,000,000. The herbage where such lambs are grazing, however, is found to carry not more than 400 larvae per pound, so that lambs eating 20 lb. in a day will ingest some 8,000 larvae. It may be supposed, therefore, that to maintain a rate of intake of 8,000 larvae per day it is necessary to add to the pasture some 8,000,000 eggs daily, or one thousand times as many as the larvae that will become available. Ewes, however, at the same time of year, will be passing only some 900 eggs per gram of faeces, representing 800,000 eggs daily. This figure, at the same proportionate rate, would represent only 40 larvae per pound of herbage. Each ewe, therefore, if grazing on heavily infected pasture along with the lambs, would ingest and destroy some 8,000 larvae daily but would add only 800, so showing a balance to the credit side of 10 larval parasites destroyed for every one added to the pasture.

The grazing of adult stock along with the young is usually thought to be unsound on account of the danger of transmission of parasites from the resistant adult carriers to the susceptible young animals. The observations on larval intake show, however, that in heavily infected pasture at least, the presence of adult animals is a distinct advantage, and that intensive grazing with young animals alone must be regarded as a dangerous practice.

These few examples will be sufficient to show how the observations on the larvae as they exist in the actual pastures are helping to clear up the epidemiology of these group helminthic diseases, and indicate the best lines for the direction of our efforts at control. Another aspect of parasitism, and one which is of the greatest importance from the point of view of epidemiology, concerns the resistance of the host to invasion by the parasites. Until quite recently, parasites have been regarded as entering into a kind of struggle for existence with their hosts, the ultimate outcome of the struggle being either the destruction of the parasites on the one hand or the death of the host on the other. Such a view of the relationship is now recognized to be wrong, as it ignores the biological need of provision for the continuity of the parasite species. This continuity would be seriously threatened by any marked lethal action upon its host, an action that would lead in the end to the annihilation of the parasite as well. A mechanism has therefore been evolved for the maintenance of a balance, the two chief forces in this mechanism being the production of excessive

progeny on the part of the parasite and the development of a resistance to excessive infestation on the part of the host. This resistance, which has been built up during the mutual evolutionary development of the host and the parasite species, must be of a very complex nature. It may reasonably be assumed, for instance, that the common nematode parasite *Strongylus vulgaris* has been associated with the horse since an early period; that *Eohippus*, the earliest recognized equine ancestor, carried some similarly primitive ancestor of *Strongylus vulgaris;* and that the two have evolved together into what they are seen to be today. Their present immunological relations may therefore be regarded as the outcome of the repeated development of 'attack' mechanisms on the one hand and 'defence' mechanisms on the other, and must now be of a very complicated nature and difficult for us to unravel.

The laboratory side of this study of parasitological immunity has received a considerable amount of attention during the past fifteen years. The mechanism, in general, conforms to that of bacteriological immunity, although the relatively large size of helminth parasites and their localized nature has led to certain differences in the approach to its investigation. There has been a tendency, for instance, to draw a distinction between resistance to the actual infestation itself and resistance to the effect of infestation, a distinction which could hardly be made for microscopic parasites, where 'effects' of parasitism are almost indispensable for the first recognition of its occurrence.

The most definite kind of immunity is that due to out-and-out incompatibility of host and parasite. Age immunity, of which there are one or two good examples in parasitology, may be regarded as of the same nature; but the branch of immunity which most concerns the veterinary parasitologist is that of resistance acquired as a result of previous infection. The greater part of the laboratory work on this acquired immunity has been done on hookworms in dogs, on stomach worms in sheep, and on a small nematode, *Nippostrongylus muris*, in rats. The immune response is found to develop very slowly, compared with the rapid rate of the development of acquired immunity to many bacterial infections. No doubt the very different rates of increase of the two kinds of parasites in the animal body have some connexion with this variation. Bacteria multiply rapidly in the host and so call forth a rapid response of the defence mechanisms, whereas the increase of parasitic helminths is, in comparison, a slow process, depending entirely upon the gradual acquisition by the host of eggs or larvae from the environment; there is therefore no necessity for a rapid response of the defence mechanisms.

One other manifestation of immunity to helminth parasites is that of 'premunition,' or the resistance of a host to further infection of a parasite that it is already carrying. This kind of resistance operates only so long as the infestation persists, and has been clearly demonstrated in the association of one or two cestode cysts with their hosts. It is not unlikely that premunition also plays its part in the protection of grazing animals against some of their nematode parasites, for small infestations of these worms are almost invariably carried, even by the most resistant adult hosts.

Because of the persistence of this residual infestation, and also, perhaps, on account of the slow rate of its development, there appears to be a tendency to regard helminthic immunity as a subject for academic study, without practical importance where disease among farm animals is concerned. This, however, is an erroneous conception, as becomes apparent when the epidemiological aspect of the resistance is considered. The food of grazing animals is subject to continuous contamination with their own faecal matter; the eggs of their parasites reach the pasture by the million per day from each moderately infested animal; the daily intake of infective larvae is a matter of thousands; and the grazing animals would be quite unable to survive the resulting heavy infestation were it not for the development of this powerful resistance. Acquired helminthological immunity is a very strong immunity. It is usually adequate for the complete protection of adult animals that may be grazing on pastures where young animals, not so protected, are dying of helminthiasis, and its place in the epidemiology of parasitic disease is of the greatest importance. It is not unlikely that a considerable part of the future endeavours of the veterinary parasitologist will be directly aimed at the investigation of methods by which this host resistance may be encouraged, and maintained at its maximum potency. Acquired immunity is the *natural* protection. In a state of nature it is adequate to protect the host in all but the most unusual stresses, and there is no doubt that under agricultural conditions its operation may be considerably assisted.

One of the directions in which these endeavours may be made is in the avoidance of conditions

FIGURE 1 – *Concentration of strongyloid (nematode) eggs collected by salt flotation from the faeces of a healthy lamb carrying a normal infestation of the adult worms.*

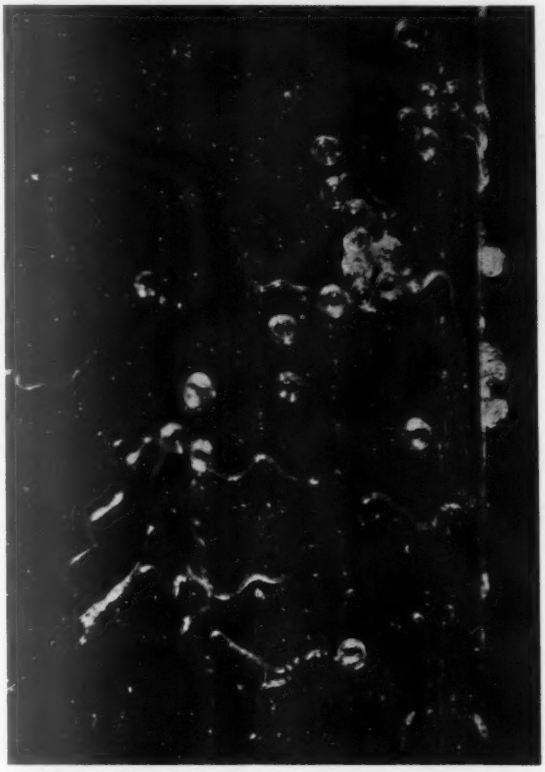


FIGURE 2 – *Infective strongyloid (nematode) larvae on a blade of grass.*

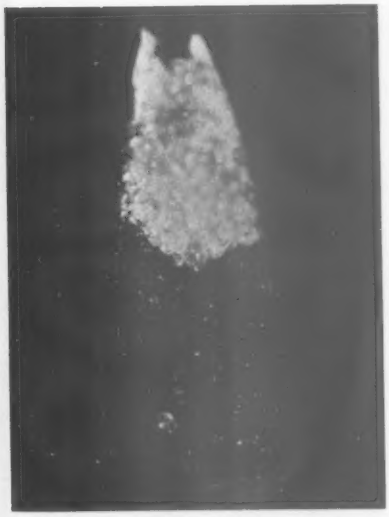


FIGURE 3 – *Mass of strongyloid larvae on the top of a heavily infected blade of grass. Specimens such as this may occasionally be found in the region of deposits of horse faeces.*

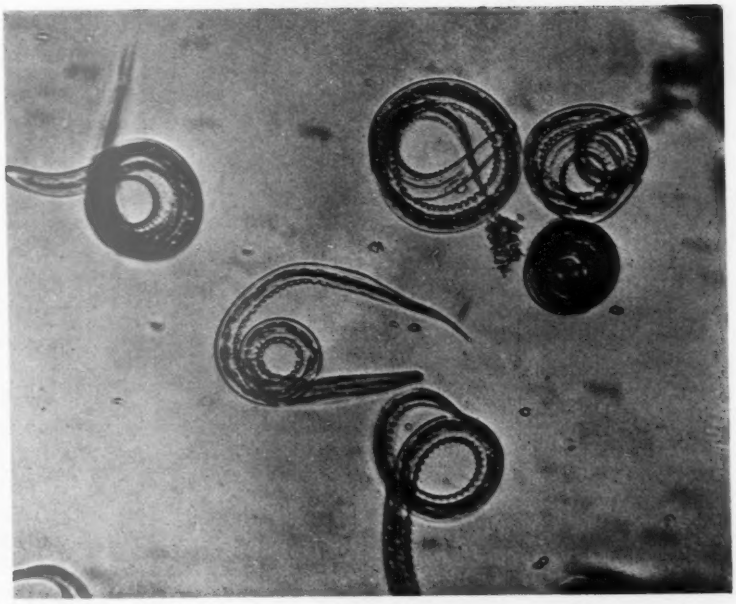


FIGURE 4 – *Infective strongyloid larvae showing the protective sheath (thrown into folds on the inner curvature), which renders them very resistant to adverse weather conditions.*

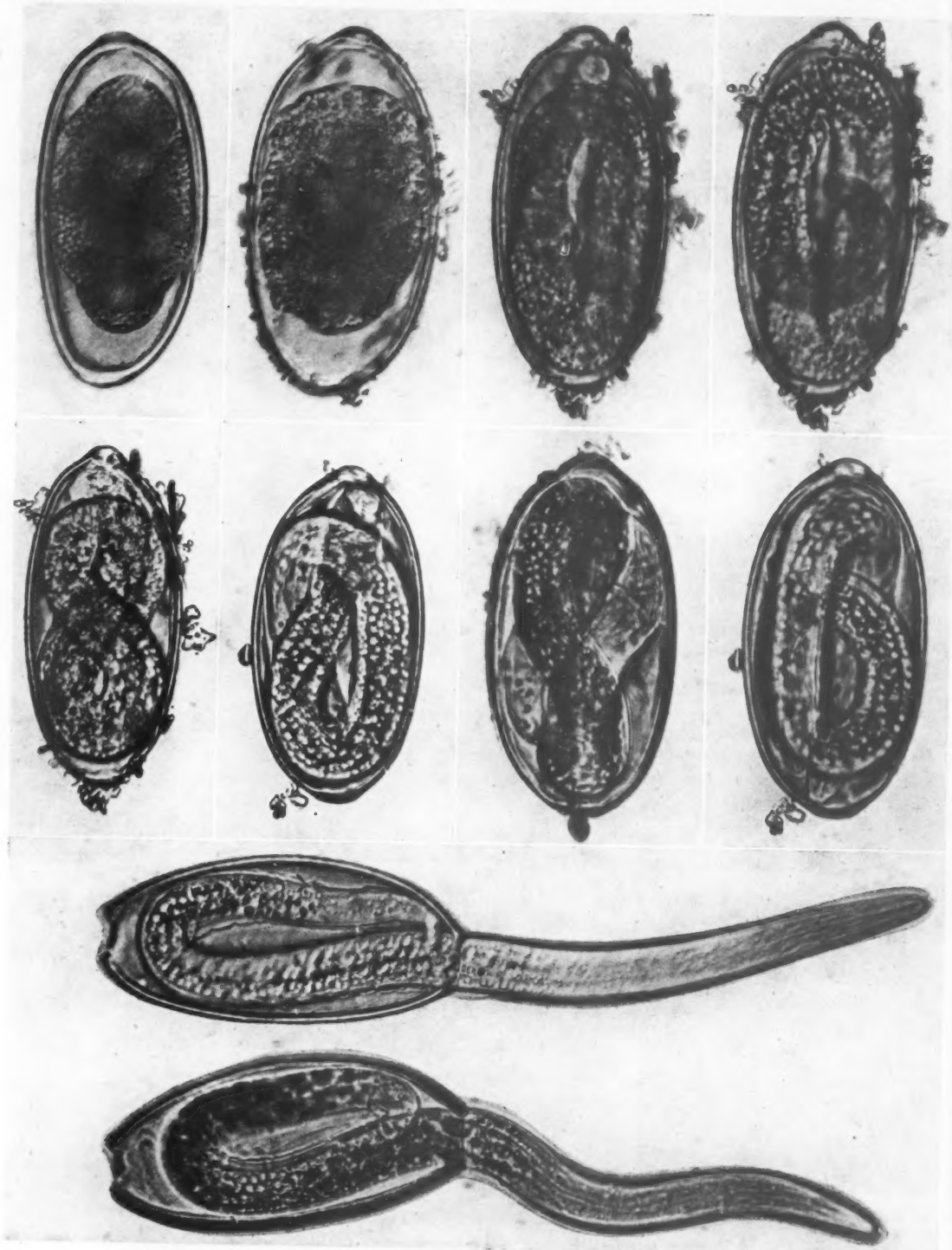


FIGURE 5 – *Development and hatching of the larvae of the strongyloid worm* Syntamus trachea *photographed on successive days. The eggs of most of the strongyloid worms of grazing animals reach the hatching stage within* 24 *hours.*

that tend to delay the establishment of immunity or to break it down when once it has been formed. It has been shown under experimental conditions, for instance, that certain mineral deficiencies and vitamin deficiencies are able to do this, as may also a diet of a very poor general quality.

Medical investigations into the epidemiology of bacterial diseases have, however, led to the conclusion that diet is of secondary importance. Some investigations into helminthic disease appeared to confirm this, as it was found necessary to modify the diet to such an extent as to reduce the weight of the host before any effect upon parasitism could be shown. This laboratory conclusion appears to have been a hasty one, however; for inquiry into the agricultural conditions of the maintenance of stock reveals that the ordinary nutritional stresses incumbent upon the seasonal variation in growth and quality of herbage are very great indeed, and that the economic need for the sparse feeding of store animals often results in their being kept alive on a diet that is considerably below the requirements for full maintenance. Towards the end of a dry summer ewes and lambs may have great difficulty in finding sufficient food on the bare pastures; and, as a direct result of their low diet, hill sheep may actually lose one quarter of their weight during the winter months, while store cattle often pass the winter in a state of progressive emaciation. Taking the larger view, therefore, of grazing animals and their parasites under actual agricultural conditions, it must be concluded that, contrary to the opinions of laboratory epidemiologists, the influence of diet upon parasitism may be of very considerable importance.

The general trend of helminthological investigation may be said, therefore, to be in the direction of epidemiology, and to be proceeding through three channels: the effect of the hosts' environment on the parasites; the effects on the parasites of the development of immunity in a group of hosts; and, lastly, the effect of parasiticidal treatment. Trial and error methods of investigation still produce occasional successes in the revelation of new and better anthelminthic substances, so that great advances may be made in that direction, and greater still when at last the rationale of anthelminthic action is understood. Even in the sphere of treatment, however, the epidemiological trend may be seen, as for example in the recognition of the need for treatment to be applied to the whole group of animals, affected and unaffected individuals alike, and for finding (*a*) the most advantageous time of year at which to apply treatment, (*b*) the age of the group when treatment is most likely to give results, (*c*) the best use of treatment to assist the establishment of immunity in the group, and (*d*) the benefit to be derived from the treatment of groups of animals affected to only a slight degree, as in the recently recognized subclinical parasitic gastritis of sheep.

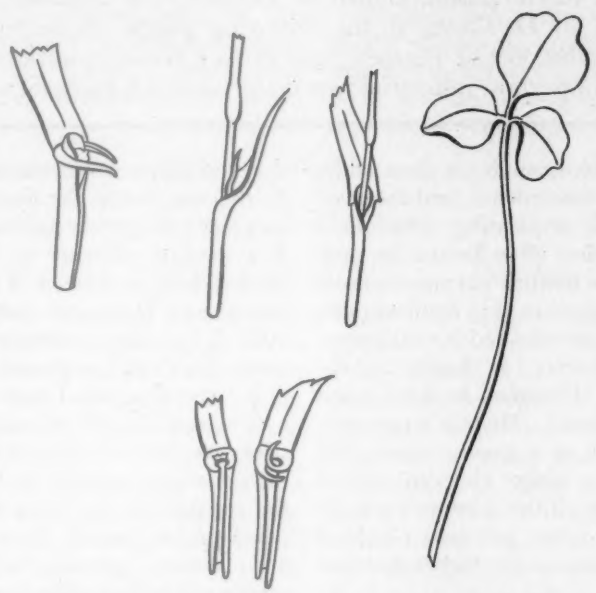


FIGURE 6 – *Junctions of blade and sheath of the leaf in different grasses showing the structure which prevents the ascent of strongyloid larvae. There is no obstacle to the ascent of the clover leaf and most of the larvae are found on the upper side of the trifoliate lamella.* (*The photographs were taken by Mr A. Norman of the Veterinary Laboratory, Ministry of Agriculture.*)

The field for the immediate future will doubtless be that of chemotherapy. As yet, the modern methods of investigation have scarcely been applied to veterinary parasitology; but there is every reason to suppose that their employment, which is already beginning, will be rewarded by the same success that has been obtained in other branches of medicine. Our present knowledge of the parasites and of their association with disease will then enable us to use any new and effective parasiticidal drug to the best advantage, and help us to establish more satisfactory control than we are able to do at the present time.

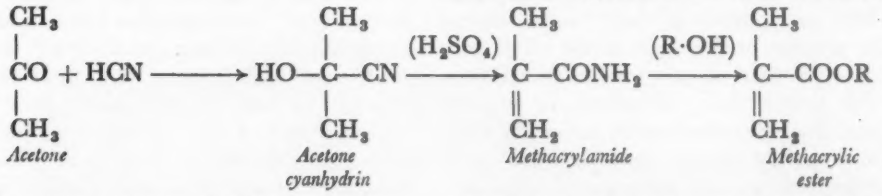
'Perspex': methyl methacrylate polymer

A. CARESS

Modern chemistry is supplying the world with entirely new products, which it would be inaccurate to regard as mere substitutes for older ones. Among the most useful of them is the solid transparent thermoplastic known as 'Perspex,' the chemistry and applications of which are described by Dr Caress in the following pages. A decade ago methyl methacrylate, the parent substance of 'Perspex,' was still a laboratory curiosity: today it has been transformed into an important industrial raw material and is manufactured on a large scale.

The names of organic compounds are dictated by scientific accuracy and convenience, and therefore cannot always be simple or pleasing. Much-used organic materials are thus often known by their trade names rather than by their chemical names. One of these is polymerized methyl methacrylate, which in the form of sheet and rod is well known as 'Perspex' in this country, as 'Lucite' in the United States, and as 'Plexiglas' in the United States and on the Continent. There is a tendency to use the word acrylic as a generic name, but there is no avoiding the longer chemical title of polymethyl methacrylate, if the substance is to be distinguished from the softer polymers obtained from esters of acrylic acid or the higher esters of methacrylic acid.

The first preparation of an acrylic monomer was reported by Frankland and Duppa in 1865 [6]. This was ethyl methacrylate, and its tendency to polymerize was noted by Fittig and Paul in 1877 [5]. Meanwhile Caspary and Tollens in 1873 [3] had described the preparation of some esters of acrylic acid, and the polymerization of methyl acrylate was reported by Kahlbaum in 1880 [9]. Systematic work in the acrylic field started early in the present century, when Röhm followed up his academic researches [10] by taking an active part in the industrial development of acrylic ester polymers in Germany.



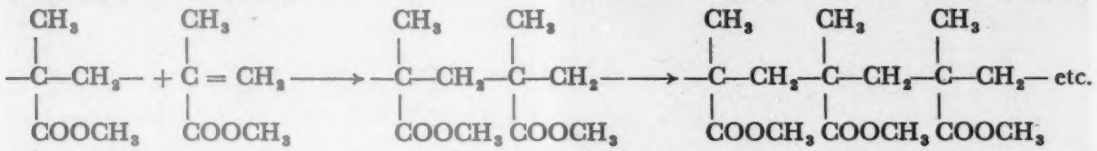
During the earlier chapters of this work Röhm was interested mainly in softer products, for use in lacquers and safety glass or as rubber substitutes, though it is possible that methyl methacrylate polymer was examined by Röhm even if he did not realize the potentialities which lay in its greater toughness and hardness. Indeed, there is a passing reference to the polymerization of methyl methacrylate in a Swiss patent, filed by Röhm and Haas and published in England in 1931 [11]. About the same time Chalmers was granted a Canadian patent [4] claiming a method of polymerizing ethyl methacrylate.

Rowland Hill [7] of Imperial Chemical Industries was the first to study methyl methacrylate monomer and polymer in detail and to appreciate the possibilities; and from this point the technical development started. However, it was only after an economic process for synthesizing methyl methacrylate had been invented in Britain that large-scale production became feasible. The British synthesis which marks the beginning of the development of methyl methacrylate as an industrial chemical was discovered in the I.C.I. laboratories and was published in a patent in the name of Crawford [8]. This synthesis from acetone, hydrocyanic acid, sulphuric acid, and methanol was improved in succeeding years [1] and is the process used in large-scale manufacture both in this country and abroad. It is also applicable, by varying the alcohol, to certain other esters of methacrylic acid. The chemical reactions are summarized in the following equations, in which R represents the alcohol radical:

Methyl methacrylate is a liquid of specific gravity 0·95 freezing at − 48° C and boiling at 100° C. It has a characteristic and now familiar odour. It is safe to transport and store in the pure

state, without the addition of polymerization inhibitors, so long as the temperature is not allowed to get too high. It can be polymerized to a rigid transparent solid by a variety of means, of which at least two have been developed industrially. These are the granular polymerization process [2] and the polymerization-casting process.

Polymerization occurs by activation of the monomer molecule, usually conceived as an opening of the double bond, followed by the rapid addition of unactivated monomer molecules to form long polymer chains:



The average number of monomer units in a polymer chain is 500–600 for granular polymers and 1,800–3,000 for cast polymers, though values outside these limits can be obtained. The chain lengths quoted are necessarily approximate, being based on Staudinger's specific viscosity method, which is not accurate for long-chain molecules even in very dilute solution. It is, however, the easiest method of estimating average chain length and is very useful as a control test. Specific viscosity is the difference in viscosity of a solution of polymer in solvent and that of the solvent, expressed as a fraction of the viscosity of the solvent itself. It is taken to be proportional to chain length and to the concentration of a sufficiently dilute solution. The constant of proportionality used in determining the limits for chain length quoted above is 0·00031 for a concentration of 1 gm per litre with chloroform as the solvent. Thus, specific viscosity = 0·00031 × number of monomer units in the polymer molecule for a solution of that concentration in chloroform.

The granular process results in a product in the form of perfect tiny spheres, illustrated in figure 1. They are the basis of clear and coloured powders, used for moulding and for the making of dentures.

The polymerization-casting process can be illustrated by the method of making the transparent sheet familiar as 'Perspex.' The monomer, with a trace of a catalyst such as an organic peroxide, is allowed to thicken and harden between glass plates in ovens at a moderate temperature, accurately controlled to a time schedule. Allowance has to be made, during polymerization, for removal of the heat of reaction and for the shrinkage of about 20 per cent. in volume which takes place. The shrinkage is constrained to occur in the thickness, and not in the area, of the sheet by means of compressible gaskets, chosen to give the desired thickness to the final solid sheets. The sheets, sandwiched between glass plates, are stripped by a special process from the glass, which is washed and dried mechanically and used again.

'Perspex' is a transparent, colourless thermoplastic of specific gravity 1·19. It is normally supplied in flat sheets up to $\frac{3}{4}$ in. thick and up to 54 in. × 48 in. in area, but larger sheets are made for special requirements. The block shown in figure 2 is a more striking illustration of the polymer in bulk. The commercial varieties usually contain a small percentage of a plasticizer, such as dibutyl phthalate, which is added to the monomer before polymerization. Its effect is to lower the softening temperature, and hence the temperature to which the sheet has to be heated (about 120° C) to enable it to be shaped into useful forms. There are, however, unplasticized varieties, including a special optical grade used in the manufacture of lenses and prisms, illustrated in figure 3. For the making of achromatic doublets, pure polystyrene is used as the 'flint' component, polymethacrylate corresponding to the 'crown.' A few of the physical properties of plasticized 'Perspex' and the two optical materials are shown in the table on page 158.

As might be expected from its molecular structure, with short polar side-chains, 'Perspex' has good mechanical properties. It is also a good electrical insulator, but it cannot, of course, compare in power factor with hydrocarbon polymers such as polythene and polystyrene. No short table of properties, however, can bring out that balance of chemical, mechanical, and optical properties which has made 'Perspex' pre-eminent among transparent plastics. It is tough enough to stand rough usage down to the lowest temperatures encountered by aircraft, without the brittleness of the inorganic glasses. In common with almost all plastics, it absorbs a small amount of water, but, unlike the majority, it is unaffected in appearance, dimensions, and physical properties by the absorbed moisture. The rate of diffusion of water vapour through 'Perspex' is even lower than through polystyrene. It is colourless and

PHYSICAL PROPERTIES

Materials	Polymethyl Methacrylate		Polystyrene
	Plasticized ('Perspex')	Unplasticized ('Transpex' 1)	Unplasticized ('Transpex' 2)
Mechanical			
Specific gravity at 20° C	1·19	1·189	1·053
Tensile strength (lb./sq. in.):			
At 40° C	5,000	—	—
20° C	7,000–9,000	10,000–11,000	5,000–6,000
−60° C	14,000	—	—
Cross breaking strength (lb./sq. in.) at 20° C	12,000–16,000	16,000–17,000	10,000–12,000
Modulus of elasticity in bend (lb./sq. in.) at 20° C	450,000	480,000–520,000	450,000–500,000
Thermal			
Softening temperature (empirical test)	78° C	105° C	102° C
Coefficient of linear expansion per ° C	$97{\cdot}5 \times 10^{-6}$	80×10^{-6}	86×10^{-6}
Thermal conductivity (C.G.S. units)	$5{\cdot}0 \times 10^{-4}$	$3{\cdot}5 \times 10^{-4}$	$2{\cdot}0 \times 10^{-4}$
Optical			
Refractive index $\left(n_D^{20}\right)$	1·4949	1·4900	1·5900
Relative dispersion $\left(\frac{n_D-1}{n_F-n_C}\right)$	53·7	57·5	31·0
Reduction in intensity of visible light passing normally through sheet	8 per cent.	8 per cent.	10 per cent.
	(almost entirely due to reflection losses)		
Electrical			
Dielectric strength on $\frac{1}{8}$ in. thick specimen (volts/mil):			
Dry	390	—	500
After 24 hours in water	380	—	500
Permittivity:			
At 1 megacycle/sec.	2·8	—	2·3
3,000 megacycles/sec.	2·6	—	2·5
Power factor:			
At 1 megacycle/sec.	0·02	—	0·0006
3,000 megacycles/sec.	0·012	—	0·0005
Volume resistivity (ohm–cm.)	10^{15}	—	10^{17}

remains so after years of exposure to sun and rain. Consequently its possibilities as a vehicle for 'solid colour' are limited only by the availability of suitable light-fast dyes and pigments. It can be coloured throughout in opaque colours or in pastel tints.

'Perspex' has no effect on, and is itself unaffected by, a variety of corrosive inorganic compounds. It is, for example, unchanged by long periods of immersion in sea-water and exposure to dry or moist gases, such as sulphur dioxide, hydrogen sulphide, oxides of nitrogen, ozone, etc. Concentrated alkalis and mineral acids up to about 30 per cent. strength have no effect. Certain classes of organic solvents dissolve 'Perspex' completely, e.g. some aromatic hydrocarbons such as toluene, simple esters such as ethyl acetate, the lower ketones such as acetone, and chlorinated bodies such as chloroform and ethylene dichloride. Such solvents are used in making adhesives with which panels can be cemented together. Methyl methacrylate itself is among the best solvents for its own polymer. During the course of polymerization there is a continuous change from the limpid monomeric liquid through a 'syrup' of gradually increasing viscosity, which is a solution of polymer

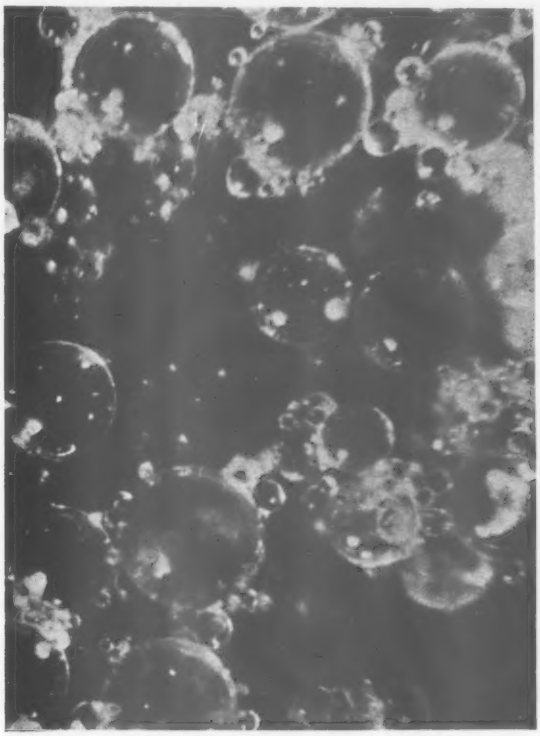


FIGURE 1 – *Photomicrograph* (× 100) *showing methyl methacrylate polymer in the form of hollow spheres as produced by the granular polymerization process.*

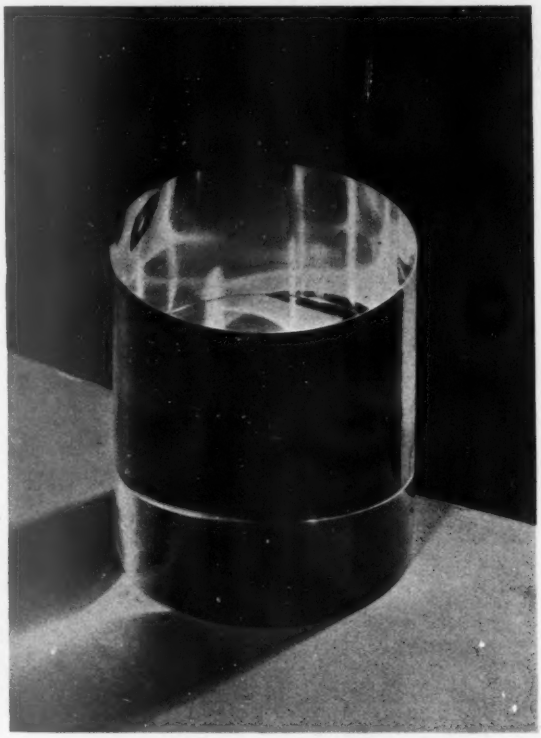


FIGURE 2 – *Solid block of cast methyl methacrylate polymer.*

in monomer, to a solid solution of monomer in polymer, and finally to polymer substantially free from monomer. Most organic compounds, other than those named, have little or no effect on 'Perspex.'

Research on the structure of methyl methacrylate polymers is hampered by their failure to form crystals, thus immobilizing the powerful weapon of X-ray analysis. This behaviour is no doubt associated with the chemical complexity of the monomer unit compared, for example, with ethylene, the progenitor of the general type $CH_2 = CR_1R_2$ to which methyl methacrylate, vinyl chloride, styrene, etc., belong. There is evidence from solubility studies that pure polymethyl methacrylate is made up of linear polymer chains with a fairly broad distribution of the number of monomer units per chain around the average number. Although cross-linking of the chains can be achieved by co-polymerizing with a small quantity of a monomer with two ethylenic double bonds—such as glycol di-methacrylate—the pure polymer is believed to be substantially devoid of branched or cross-connected chains.

FIGURE 3 – *Group of plastic lenses and prisms, including achromatic doublet of polymethyl methacrylate and polystyrene.*

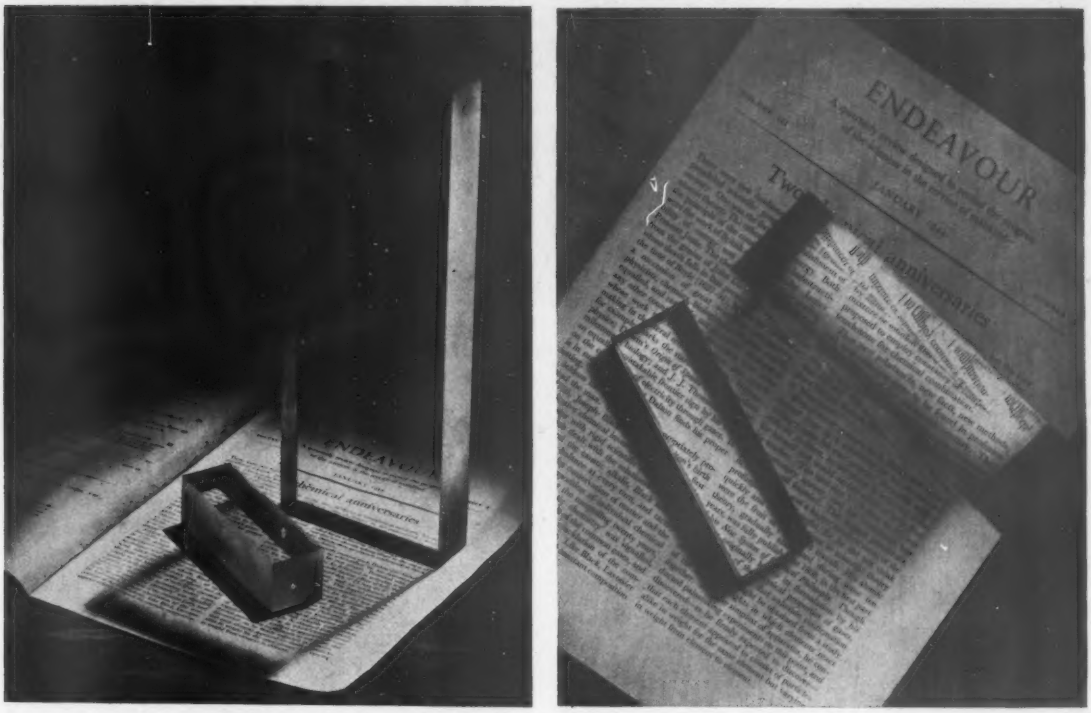


FIGURE 4 – *Photographs illustrating the remarkable transparency of 'Perspex.' The photograph on the left is a side view of blocks* 1 *in. and* 1 *ft. high resting on a page of print. The right-hand photograph shows the print taken downwards through the 'Perspex.'*

On pyrolysis at around 400° C, the polymer is 'depolymerized' rapidly to methyl methacrylate monomer in high yield, with only small quantities of by-products. The depolymerization of the plasticized polymer gives a crude product in lower yield, as it contains the products of decomposition of the plasticizers.

Heating the polymer at somewhat lower temperatures while subjecting it to mechanical friction, as, for example, between heated rolls, results in a lowering of average chain-length by breaking down the longer molecules. Examination of 'Perspex' before and after this treatment, by means of the ultracentrifuge, indicates that the lowering of average molecular weight is accompanied by a narrowing of molecular weight distribution. This deduction is supported by the observed fact that the heat-treated product has a sharper softening range than the untreated polymer—a fact of technical importance in the production of varieties for moulding by the injection process. The wide softening range distinguishes 'Perspex' from the highly crystalline polymers such as polythene, nylon, and polyvinylidene chloride, which have relatively sharp melting-points.

The lack of any tendency to crystallize facilitates the production of a polymer in an optically isotropic form, such as 'Transpex' 1. By attention to detail, three desirable properties can be combined. The material can be made optically homogeneous, highly transparent, and constant in refractive index from sheet to sheet. The deviation from optical homogeneity, as measured by the interferometer, can be made as little as, or less than, that of the finest inorganic optical glasses. The transparency to ordinary white light is such that the eye can scarcely detect the difference in looking through a fraction of an inch and several feet of the material (see figure 4). The refractive index can be kept constant to 0·0001 over a whole series of sheets—a result which cannot be reckoned on unless the starting material is a pure synthetic chemical. Unplasticized 'Perspex' is transparent to ultra-violet light down to 2,900 A, and the plasticized variety transmits down to 3,000 A.

Plastics have sometimes been limited in use by being regarded as substitutes, both before the war

FIGURE 5 – *Photograph of a bovine vaginal speculum used in veterinary work. It has a light source at one end and the light is conveyed through the 'Perspex' tube wall to the other end, thus permitting internal inspection ('Coldlite' bovine vaginascope, British Patent* 551146).

when they were replacing wood, metals, and ceramics, and during the war, when they were called upon to make good the shortages of other materials. Although 'Perspex' is transparent, it is wrong to think of it as a substitute for glass. It has found its most important war application in those secondary structures on aircraft which must be seen through, such as the shaped roofs of pilots' cabins, gun-turrets, and observation domes (see figure 6).

The chief disadvantage of 'Perspex' as a transparent sheet material is that, like many other plastics, it lacks resistance to abrasion. Its perfect clarity allows every faint scratch to be seen in sharp relief when viewed at the correct angle, though when coloured in the bulk it does not show up scratches nearly so markedly. With the growth of experience in handling the material, troubles from this cause have not proved as serious in service as might have been expected, and superficial scratches acquired in service can be removed easily by polishing. Surface scratching might be a more serious defect in plastic optical components, since the polishing out of scratches,

FIGURE 6 – *Parnell turret made of 'Perspex.'*

FIGURE 7 – *Interior photograph of the 'Flying Scotsman' showing the use of flat 'Perspex' panels separating the back-to-back seats all along a compartment.*

FIGURE 8 – *Motor coaches with curved 'Perspex' side lights.*

which is quite practicable for non-optical uses, would not be permissible for precision lenses and prisms. Fortunately it has been found that the usual care given to optical instruments is enough to protect the lenses and prisms from serious harm.

In the optical field plastics are no longer substitutes. For example, the production of aspherical lenses from inorganic glasses is prohibitive in cost for many instruments, since each lens has to be ground and polished individually; but with transparent plastics the contour can be repeated almost indefinitely from one accurate model.

A less important defect of 'Perspex,' also shared by many other plastics, is a high coefficient of expansion, which is 7 to 9 times that of steel and 10 to 12 times that of glass. Although troublesome, this can be allowed for by the use of suitable gaskets.

Use has been made of the high transparency of 'Perspex' in 'piping' light round bends. Light is led from one end of a bent rod or tube through the material to the other end, from which it emerges only slightly diminished in intensity. The curves and the light-source are arranged so that the light is totally internally reflected and kept inside the rod or tube until it reaches the desired point. Such devices are used by dentists for illuminating the interior of the mouth, and by surgeons for providing light at the seat of intricate operations. The method has also been applied successfully to veterinary operations, of which an interesting example is illustrated in figure 5. This is a vaginal speculum, the use of which has been described recently by Steele-Bodger [12]. Surgeons are also experimenting with 'Perspex' for a variety of uses, including artificial eyes, splints, supports, and cranial plates.

'Perspex' has already been used to a small extent in transportation other than in aircraft. The same shaping techniques have been used to make curved panels for motor-cars and speed-boats. Applications of flat sheet in railway vehicles and curved panels in road transport are illustrated in figures 7 and 8.

'Perspex' is also being introduced as a raw material for fabricating by hand, alongside wood and metal, in schools, training centres, and rehabilitation centres. Industrial artists are beginning to appreciate the intrinsic qualities of the material and to create new designs in harmony with those qualities.

REFERENCES

[1] British Patents 427810, 440967, 456533.

[2] British Patents 427494 and 444257.

[3] CASPARY and TOLLENS. *Ann.* 1873, **167**, 247-252.

[4] CHALMERS. Canadian Patent 314116.

[5] FITTIG and PAUL. *Ann.*, 1877, **188**, 54, 55.

[6] FRANKLAND and DUPPA. *Ann.*, 1865, **136**, 12, 13.

[7] I.C.I. and HILL, R. British Patent 395687, 17th November, 1931.

[8] I.C.I. and CRAWFORD, J. W. C. British Patent 405699, 12th August, 1932.

[9] KAHLBAUM. *Ber.* 1880, **13**, 2348–2351.

[10] RÖHM. *Ber.*, 1901, **34**, 573, 574.

[11] RÖHM and HAAS. Swiss Patent 146563.

[12] STEELE-BODGER. *Vet. Rec.*, 1944, **56**, 34.

Book reviews

SCIENCE AND CIVILIZATION

The Impact and Value of Science, *by D. W. Hill. Pp.* 88. *Hutchinson's Scientific and Technical Publications, London.* 1944. 7*s.* 6*d. net.*

Books on this subject tend to resemble each other closely; but some of Dr Hill's opinions and proposals are out of the common, as the following quotations will show:

'Scientists, in their writings, are too truthful, and that makes them dull.'

'Science, in its passion for exactitude, is becoming increasingly mathematical and seemingly divorced from reality.'

(In the chapter on 'Science and Politics') 'There is, however, every reason to believe that a government of scientists might be a most truly democratic government.' 'Are we, then, to advocate a government of scientists? Why not?'

The author proposes that students who wish to become specialist teachers in secondary schools should not, as at present, take university honours in their subject, but should have instead a four years' course in a Faculty of Education. It may perhaps be felt that this is giving undue importance to what in medicine is called 'bedside manner'; and it may be questioned whether Dr Hill is devising the best way to secure what he so much desires in the specialist teachers of science, viz. the scientific habit of mind.

The account of the triumphs of science in industry, though brief, is excellent, and the book as a whole is interesting reading.

E. T. WHITTAKER

A PICTURE OF THE UNIVERSE

The Universe Around Us, *by Sir James Jeans. Pp.* $x + 297$, *with* 32 *plates. University Press, Cambridge. Fourth edition.* 1944. 15*s. net.*

To set out to describe within the compass of a book of moderate size what astronomy has to tell us about the universe in which we live is a task that is far from easy. Sir James Jeans succeeds in presenting a well-balanced account of the methods and results of modern astronomical research. A wide field is covered; a whole chapter, for instance, is devoted to modern atomic theory, because a knowledge of this is necessary in order to understand the processes that occur deep in the interior of a star, the source of stellar energy, and the course of evolution of a star. Physics, chemistry, and geology are all, in fact, called upon to assist in the interpretation of the results of observation.

The problems of cosmogony and evolution, to the solution of which Sir James Jeans has himself made important contributions, receive special attention. He is careful to emphasize that the picture is fragmentary and can claim no finality: 'we are not describing the mature convictions of a man so much as the first impressions of a new-born babe which is just opening its eyes.'

In preparing this fourth edition for press, an account is included of the principal advances in astronomy that have occurred in the decade since the third edition appeared, and the opportunity has been taken to make a thorough revision of the book, which has been largely rewritten.

The book is written with Sir James Jeans's usual clarity of style and facility of phrasing. Many striking illustrations and analogies are used to impress a point on the reader; thus, for instance: 'Each time the child throws its toy out of its baby-carriage, it disturbs the motion of every star in the universe.' The plates are numerous and well selected, whilst the printing is of the high standard that we expect from the Cambridge University Press. The book can be confidently recommended as one of the best expositions of the subject in simple language, and it should pass through many more editions.

H. SPENCER JONES

THEORY AND DESIGN OF WAVE-FILTERS

Wave-filters, *by L. C. Jackson. Pp. vii* + 107. *Methuen & Company Limited, London.* 1944. 4*s.* 6d. *net.*

Wave-filters are electrical networks that pass alternating currents whose frequencies lie within a selected range and suppress or attenuate those of all other frequencies. They are an essential feature of almost every development of telecommunication. The student of physics or radio, to whom a knowledge of them is becoming increasingly important, has hitherto had to pick out certain chapters or sections from the large and highly technical standard works on electricity, radio, or telecommunication engineering, where he has found (often after a long search) the available information to be too elementary or too condensed for his needs or, in some cases, a compilation of design formulae and diagrams.

This monograph, a notable addition to an important and well-known series, will do much to remove his difficulties. It provides a readable and concise account of electrical wave-filters of various types, with enough of the underlying theory to enable the reader to use the many detailed formulae employed in their production, and to read profitably the larger works describing at greater length the technical details and practical applications. As a guide to further reading a bibliography of important books and original papers is provided. The application of the theory of wave-filters to mechanical and acoustical oscillatory systems is briefly described; this is a particularly good example of the interaction of advances in various branches of physics.

The text includes 64 well-prepared figures, mostly circuit diagrams and graphs, and is adequately indexed.

W. JEVONS

OUTLINES OF ORGANIC CHEMISTRY

Principles of Organic Chemistry, *by Sylvanus J. Smith. Pp. viii* + 569. *Macmillan & Company, Limited, London.* 1944. 15*s. net.*

This three-year course deals first with molecular formulae, physical properties, valency of carbon, classification, isomerism, and stereo-isomerism, before passing on to the systematic survey of aliphatic, aromatic, heterocyclic, and homocyclic compounds which constitutes the bulk of the book. In teaching practice, some of the initial topics could scarcely be handled before a single organic compound had been considered. Unusually, the book opens without a definition of organic chemistry. In a somewhat rigid treatment, the author takes into account the modern conceptions of valency and reactivity and gives a sound and competent factual presentation of the subject; but it should be mentioned that all historical background is lacking and that as a rule no particular attention is paid to industrial, economic, or biochemical aspects. There are numerous

figures and diagrams, and the text and formulae are well printed. The text is not free from errors: the statement that 'Wohler' discovered 'the most important synthesis of urea' (p. 217) is inexact; 'the relation of object and mirror image' is not characteristic of optical antipodes unless object and image are distinct (p. 249); sodium ammonium racemate is not the sodium salt of racemic tartaric acid (p. 249); *d*- and *l*-carvone occur in oils of caraway and spearmint, respectively, rather than in those of 'carroway' and 'mint' (p. 509); and it is not usual to represent terpin hydrate as an open-chain compound (pp. 510, 512).

JOHN READ

WATER ANALYSIS

The Chemical Analysis of Waters, Boiler- and Feed-waters, Sewage, and Effluents, *by Denis Dickinson. Pp. xii* + 140. *Blackie & Son Limited, London.* 1944. 6*s. net.*

In this little book the important determinations in the chemical analysis of waters, sewage, and effluents are concisely described, but little guidance is given in the interpretation of results. Reliable methods have been well chosen, and it is a practical, up-to-date bench-book which will prove useful in laboratories undertaking water and sewage analyses. In preparing another edition, which will certainly be demanded, the author should mention the modifications of Hatfield's method for the determination of aluminium, described in *The Analyst*, 1943, **68**. There might also be included a sensitive method, such as Denigès' (modified), for phosphates in potable waters, and a method for the determination of phenoloids. In the determination of calcium in potable waters N/25 or N/80 permanganate would be preferable to N/8, and electrical conductivity, being concerned with total solids, could properly be included in chapter II instead of chapter XIII. Warning should be given that the diluting water used in B.O.D. determinations must be free from antiseptics such as chlorine and copper. Such statements as 'It is rather unusual for a natural water . . . to have no colour,' and '500 ml. of a good quality water . . . should be evaporated to dryness' (in the determination of total solids) require modification.

E. V. SUCKLING

FUNGI: TO EAT OR NOT TO EAT?

Edible Fungi, *by John Ramsbottom. Pp. ii* + 35, *with* 16 *coloured plates. Penguin Books Limited, Harmondsworth and New York.* 1944. 2*s. net.*

This handsome little volume appears at an opportune time, for efforts have been made during the war to popularize the eating of certain kinds of wild fungi in this country as a means of adding variety to a somewhat monotonous diet. Before the war only the mushroom was commonly eaten in Britain, unlike the custom in other European countries. By lectures and exhibits at the Natural History Museum, London, and in other ways, the author of this book has done much to teach the public that many other kinds of fungi are at least as wholesome and delicate in flavour as the mushroom. In this 'King Penguin' Dr Ramsbottom describes twenty common edible species in interesting detail, and illustrates them by such excellent coloured drawings by Rose Ellenby that no mistake can be made in identification. Correct determination is important because many toadstools are unwholesome and a few are really poisonous. Recipes for cooking are given, but epicures will probably long for the time when more adequate supplies of butter are available. The Morel, Blewits, Chanterelle, Fairy Ring Champignon, Beefsteak Fungus, and Giant Puff-ball are among the species described, but the subterranean Truffles are omitted, doubtless owing to their extreme rarity in Britain except in a few favoured localities.

F. T. BROOKS

PRINCIPLES AND APPLICATIONS OF GEOLOGY

Geology in the Service of Man, *by W. G. Fearnsides and O. M. B. Bulman. Pp.* 158, *with* 8 *plates.* (*A Pelican Book.*) *Penguin Books Limited, Harmondsworth and New York.* 1944. 9*d. net.*

The appearance of a Pelican Book on geology is to be welcomed, for too little has been done in recent years to interest the lay reader in this science, which is so fundamental to an understanding of many problems, and yet is sadly neglected in British educational curricula. The title would perhaps imply that this book deals only with the applications of geology, but the authors have adopted a wider interpretation, and the first half of the book is essentially a general introduction to the principles of geology. This part, on 'The Nature of the Evidence,' includes chapters on the crust of the earth, the building of continents, the development of scenery, an epitome of the geological history of Britain, and the construction of geological maps. To cover these topics in about 25,000 words has naturally involved much condensation, and some portions will be heavy reading for those with little knowledge of physics and chemistry. Within these limitations, however, the authors have performed their task admirably, and although the book is packed with information the writing is clear and stimulating.

The second half of the book deals with 'Some Applications of Geology,' and there are sections on water supply, soils, oil, engineering geology, mineral supplies for heavy industries, non-ferrous metal supplies, and gemstones. These chapters are necessarily short, but they give a clear indication of the importance of geological data in many problems. It may be hoped that this publication will extend among engineers and scientific workers an appreciation of the usefulness of the science. There are numerous clear text illustrations, and eight plates, with suggestions for further reading and a useful index. It is to be regretted that the volume is not available in a more permanent form.

A. E. TRUEMAN

METAL FINISHING BY RADIANT HEAT

The Application of Radiant Heat to Metal Finishing, *by J. H. Nelson and R. Silman. Pp. vi* + 79, *with* 37 *figures. Chapman & Hall Limited, London.* 1944. 8*s.* 6*d. net.*

This is a timely publication dealing with an industrial process which is already being widely used and which has a special application to mass-production. In writing the book, the authors have very wisely assumed that the use of the process should be accompanied by some knowledge of the physical principles involved in it, and for this reason the chapters on heat transference and paint formulation are particularly welcome. The types of plant already in use are described and illustrated, but it is made abundantly clear that, in introducing the process, careful consideration must be given to the particular design most suitable for each specific purpose.

A. J. PHILPOT

Notes on contributors

LORD RAYLEIGH,

J.P., D.L., M.A., Hon. Sc.D. (Dublin), Hon. D.Sc. (Durham), Hon. LL.D. (Edinburgh), F.R.S.,

Was born in 1875, and succeeded his father, the third Baron Rayleigh, in 1919. He was educated at Eton and Trinity College, Cambridge, of which he was a Fellow, and has had a full and distinguished scientific career. He is Chairman of the Governing Body of the Imperial College of Science, a Fellow of Eton College, and Emeritus Professor of Physics at the Imperial College. He was President of the British Association in 1938 and Foreign Secretary of the Royal Society from 1929 to 1934. From 1934 to 1936 he was President of the Physical Society. He is a Rumford Medallist and former Bakerian Lecturer of the Royal Society, and a Foreign Member of the Dutch Society of Sciences. He says that he learnt his scientific outlook mainly from his father and from Sir J. J. Thomson, of both of whom he has written biographies. He is by natural inclination prone to test ideas by experiment rather than by debate. He has, for example, investigated by experiment the often discussed question of the green flash at sunset, and has found that the observed effect can readily be produced by a glass prism having the normal optical dispersive power of the atmosphere.

Lord Rayleigh is a keen agriculturist, and his stock at Terling Place, Essex, includes a well-known dairy herd.

T. MARTIN,

M.Sc.,

Is a native of London, where he was born in 1893. He was educated at Alleyn's School and University College, London, and found an early scientific interest in metallurgy. After three years of active service in France during the war of 1914–18 he went to the Royal School of Mines, London, to carry out research on the physical properties of metals at high temperatures. In 1923 he became secretary of the British Empire Exhibition of the Royal Society. Later he organized the Optical Convention of 1926, was secretary of the Institute of Physics (1926–9), and edited the *Journal of Scientific Instruments*. He was appointed General Secretary of the Royal Institution in 1929, a post which he still holds. On the outbreak of war in 1939 he served in the Army for some time, but since 1942 he has been Deputy Director of Instrument Production in the Ministry of Supply. His literary activities have included the editing of Faraday's diary and the writing of a short life of Faraday. He sums up his recreations in two words: 'country cottage.'

A. W. BALDWIN,

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Was born at Salford, and was educated at Salford Secondary School and the Universities of Manchester and London. He started his chemical career as an assistant in the research department of Levinstein Limited, a firm which later became merged in Imperial Chemical Industries. Since 1930 he has been engaged in research for I.C.I. upon surface active compounds of known constitution, and with his collaborators has very widely extended the useful range of such substances. He is a keen amateur playwright and actor, with a leaning towards comedy.

E. C. DODDS,

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Was born in 1899 and was educated at Harrow County School and the Middlesex Hospital Medical School, London. He was Goulstonian Lecturer at the Royal College of Physicians in 1934, and Harvey Lecturer in the University of New York in 1935. A member of the American Society of Clinical Pathologists, and of the Grand Council of the British Empire Cancer Campaign, he is also Courtauld Professor of Biochemistry in the University of London and Director of the Courtauld Institute of Biochemistry at the Middlesex Hospital. He has published numerous original articles on various biochemical subjects, and is editor of the *Journal of Endocrinology*. He disclaims the possession of appealing traits and of strange and fascinating hobbies.

E. L. TAYLOR,

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Was born in 1894 and was educated at King Edward VII School, Lytham St Anne's, at the Harris Institute, Preston, and at the University of Liverpool. During the war of 1914–18 he served in the Royal Army Veterinary Corps, and was mentioned in despatches and awarded a foreign distinction for work in a veterinary hospital in France. His training in parasitology was carried out at the Liverpool School of Tropical Medicine, where he held a lectureship for a short time. He subsequently studied at the Paris *Ecole de Médecine* and in the United States Bureau of Animal Industry. He now holds one of the posts of Senior Research Officer at the Ministry of Agriculture's Veterinary Laboratory. His chief work has been directed to the pathogenic significance of helminth parasites and the investigation of the epidemiology of helminthiases. He maintains that pathological parasitism is largely man-made, and that an important step towards the control of parasitic disease is to define the human interference that has given rise to the pathogenicity.

A. CARESS,

B.A., Ph.D.,

Was born in 1904 and entered Trinity Hall, Cambridge, as an Open Scholar in 1922. For a time he worked in the Cavendish Laboratory, but afterwards engaged in research on physical chemistry until joining Imperial Chemical Industries in 1928. In 1936 he was appointed research delegate director of the then newly formed Plastics Group of I.C.I., becoming development director six years later. He has been associated with research on urea-formaldehyde, methyl methacrylate, and polyvinyl chloride, and has seen 'Perspex' through from a laboratory curiosity to its present position as a large-scale plastic. During the war he has taken a leading part in the problem of the replacement of rubber by polyvinyl chloride. He is fond of outdoor games, particularly golf.

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